Zonation by ammonites and foraminifers of the Vraconnian-Turonian interval: A comparison of the Boreal and Tethyan domains (NW Europe / Central Tunisia)

Francis AMÉDRO [1]

Francis ROBASZYNSKI [2]

Abstract: Since the end of the 19th century the interval comprising the uppermost Upper Albian, the Cenomamian, the Turonian and the basal Coniacian has been subdivided, first into ammonite zones, then, beginning in the middle of the 20th century, into zones of planktonic foraminifera. These two groups, one macrofossil, the other microfossil, are particularly effective for bio-chronostratigraphy thanks to their rapid rates of evolution. But differences in the faunal makeup between the Boreal domain (northwestern Europe) and the Tethyan domain (Mediterranean) have for a long time hindered precise correlation of the two domains. Today, in a time interval covering about 16 million years, there are 29 ammonite zones in the Tethyan domain versus 24 in the Boreal one, of which 16 are common to both domains. For the planktonic foraminifera the Tethyan domain has 11 zones, the Boreal domain 10, with 7 in common.

Key Words: Cretaceous; Albian; Vraconnian; Cenomanian; Turonian; ammonites; foraminifers; zones; zonation; Tethys.

Citation : AMÉDRO F. & ROBASZYNSKI F. (2008).- Zonation by ammonites and foraminifers of the Vraconnian-Turonian interval: A comparison of the Boreal and Tethyan domains (NW Europe / Central Tunisia).- Carnets de Géologie / Notebooks on Geology, Brest, Letter 2008/02 (**CG2008_L02**)

Résumé : ***Zones d'ammonites et de foraminifères du Vraconnien au Turonien : Une comparasion entre les domaines boréal et téthysien (NW Europe / Tunisie centrale).-*** Depuis la fin du 19ème siècle, l'intervalle comprenant l'Albien supérieur élevé, le Cénomanien, le Turonien et le Coniacien basal a été subdivisé d'abord en zones d'ammonites puis, à partir du milieu du 20ème siècle, en zones de foraminifères planctoniques, deux groupes de macro- et de microfossiles particulièrement efficaces en bio-chronostratigraphie grâce à leur taux d'évolution rapide. Toutefois, des différences de compositions fauniques entre le domaine boréal (Europe du Nord-Ouest) et le domaine téthysien (Méditerranée) ont longtemps empêché des corrélations précises entre ces deux domaines. Aujourd'hui, dans un intervalle de temps couvrant environ 16 millions d'années, on dénombre 29 zones d'ammonites en domaine téthysien contre 24 en domaine boréal parmi lesquelles 16 sont communes aux deux domaines. Pour les foraminifères planctoniques, on compte 11 zones en domaine téthysien et 10 en domaine boréal, dont 7 communes.

Mots-Clefs : Crétacé ; Albien ; Vraconnien ; Cénomanien ; Turonien ; ammonites ; foraminifères ; zones ; zonation ; Téthys.

Introduction

The biostratigraphic studies that we have undertaken for several decades in the Boreal and Tethyan realms have yielded a great amount of data, so here we synthesize the information about the ammonite and foraminiferal zones recognized in the "middle" Cretaceous of the two domains (AMÉDRO, 1992, 2002, 2008; AMÉDRO & ROBASZYNSKI, 2001 a-b; AMÉDRO *et alii*, 2005; ROBASZYNSKI *et alii*, 1990, 1994). The results of a comparison of the several zones are shown on a table (Table) which provides a clear understanding of the choices made in its construction. Such a comparison of zones should not be taken as a purely academic exercise, but rather as an attempt to compare biostratigraphic intervals that should facilitate a more precise synchronization in the two domains of the events, lithologic, biologic, geochemical, eustatic that took place in the medial portion of Cretaceous times.

I – Choices made in constructing the table (Table)

The reference zonation was chosen to be that of the ammonites of Tunisia, in spite of the fact that for the middle Cretaceous two of the three stage boundaries are defined with a planktonic foraminifer and an inoceramid species. However, it appears that insofar as ma-

[1] *26, rue de Nottingham, 62100 Calais (France); Biogéosciences, UMR 5561 CNRS, Université de Bourgogne, 6 boulevard Gabriel, 21000 Dijon (France)*
francis.amedro@free.fr
[2] *Faculté Polytechnique, 9, rue de Houdain, 7000 Mons (Belgique)*
francis.robaszynski@fpms.ac.be
Manuscript online since May 17, 2008

crofossil time-markers are concerned, ammonites are both the most abundant paleontologic material and the most determinative in indicating platform deposits, be they proximal or distal (AMÉDRO in ROBASZYNSKI *et alii*, 1990, 1994).

The number of ammonite zones in Tunisia is greater than those of the Boreal domain, for at least two reasons: (i) deposition of sediments was more continuous -thus more nearly complete- for it was taking place in a basin more subsident than those of the intracratonic basins of northwestern Europe, (ii) there, starting in Albian times, connections with North American and African provinces were established and immigrants from these provinces are associated with or replace Tethyan faunas.

In the table (Table), the zones recognized or created in Tunisia are in successive boxes of the same size, but this does not mean that they are all of the same time length. This form was chosen because, although the duration of several has begun to become known (CARON *et alii*, 1999), the length of many is far from being established. Probably the work on dating volcanic ash in company with detailed cyclostratigraphic studies will add a lot to the measurement of the length of zones.

The planktonic foraminiferal zones are placed in respect to the Tunisian ammonite zones in accordance with information obtained from records of their vertical ranges made in the same sections as those that furnished the ammonites (ROBASZYNSKI *et alii*, 1990, 1994).

II - Characteristics and comparison of the two ammonite zonations of the middle Cretaceous

1 - NW Europe: Anglo-Paris Basin, Westphalia and southeastern France (Rhône valley and the Vocontian domain)

The ammonite zonation currently in use for the middle Cretaceous of NW Europe, an area that includes the historical stratotypes of the Albian, Cenomanian and Turonian stages, is one of the most precise known. Its examination calls for several remarks: (i) most of the markers of the zones have a broad geographic distribution; (ii) where it is possible, the species chosen are in the same phyletic lineage, for example in the Upper Albian-Vraconnian the succession is *Mortoniceras* with two tubercles per rib (*M. pricei*), then three (*M. inflatum*, *M. fallax*) and finally four tubercles per rib (*M. perinflatum*); (iii) except in the Vocontian domain (Mont Risou, KENNEDY *et alii*, 1996) an important gap in sedimentation marks a hiatus in the succession of ammonite faunas; (iv) in the Middle Turonian, while the chalk facies of the northern Anglo-Paris Basin and of Westphalia (KAPLAN *et alii*, 1996) contain a typically Boreal fauna with *Collignoniceras*, the "tuffeaux" (porous limestones) of the southern border of the basin (Saumur, Bourré, Poncé) and the sandstones of the Rhône valley (Uchaux) contain mixed faunas, rich in *Kamerunoceras*, then in *Romaniceras*. These intermediate areas form precious links between the Boreal and Tethyan domains.

2 - Central Tunisia

The ammonite zonation now used for the middle part of the Cretaceous succession has progressed in relation to the previous divisions recognized by PERVINQUIÈRE (1903, 1907) and DUBOURDIEU (1956). Its detail is often better to that obtained in the intra-cratonic basins of NW Europe, because of the continuous and thicker deposition, and an extraordinarily rich ammonite fauna at almost all the levels.

3 - Comparison

There are numerous kinships between the ammonite zones of NW Europe (Boreal and north Tethyan domains) and those of Tunisia (southern Tethyan domain). Nevertheless, several intervals have no direct correlation. These coincide in particular with the limits of stages (eustatic events, lowering of sea level). But on the other hand, at these levels there is the remarkable occurrence in Tunisia of the episodic occurrence of ammonites with North American affinities, successively: (i) at the limit between Albian (Vraconnian) and Cenomanian: *Graysonites* (AMÉDRO *in* ROBASZYNSKI *et alii*, 2007); (ii) in the Middle Cenomanian: *Paraconlinoceras barcusi*, *Acanthoceras amphibolum*; (iii) at the Cenomanian-Turonian boundary: *Pseudaspidoceras pseudonodosoides*, *Watinoceras* sp., *Pseudaspidoceras flexuosum*; (iv) in the Upper Turonian: *Prionocyclus novimexicanus*, *P. germari*. These succcessive phases of migration are probably linked to eustatic events (Transgressive Intervals of 3rd order eustatic cycles). All of this demonstrates the existence of numerous relationships between the Boreal and Tethyan domains, not only between northwestern Europe and Tunisia but also, in a more ephemeral way, between the North-American continent and Tunisia.

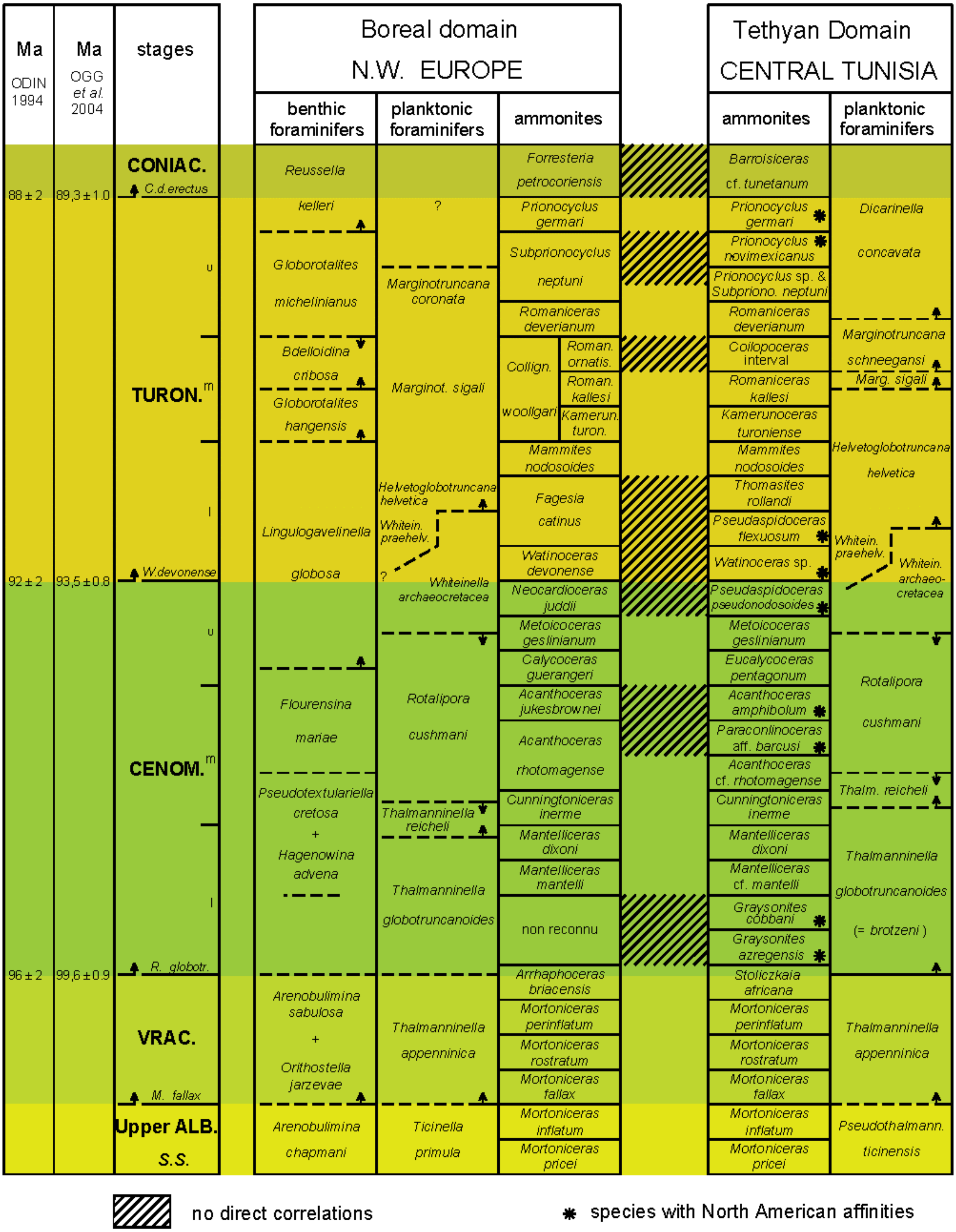

Table: An attempt to correlate the zonation of ammonites and foraminifers in northwestern Europe (Boreal domain) with that of central Tunisia (Tethyan domain). The up- and down- pointing arrows indicate respectively the first and last appearances of the taxa concerned.

III - Foraminiferal zonations

1 - Central Tunisia

The sections were made in areas where sedimentation was intermediate between platform and basin. The Kalaat Senan region is in the outer platform domain, in a distal relationship to the coast, with deposits essentially argillaceous and marly in the Albian-Lower

Cenomanian and then with the development of carbonate beds intercalated in the marls that start in the Cenomanian and continue up through the Coniacian and even higher. The marly facies delivers planktonic foraminifers with Tethyan characteristics: large (0.3 to 0.7mm, sometimes up to 1mm), the non-globular morphotypes have well-marked and often thick keels, with numerous transitional forms between species. Moreover, benthic forms with agglutinated or calcareous tests are generally associated with planktonic forms but have less significance for chronostratigraphy.

In Tunisia, the zones recognized between the Vraconnian and the Coniacian are more or less the "standard zonation" that since the middle of the 20th century has been established and improved (BOLLI, 1966; SIGAL, 1987; ROBASZYNSKI & CARON, 1979; details in ROBASZYNSKI & CARON, 1995, and in GONZÁLEZ-DONOSO *et alii*, 2007), with the succession: *Thalmanninella appenninica*, *T. globotruncanoides* (= *brotzeni*), *T. reicheli*, *Rotalipora cushmani*, *Whiteinella archaeocretacea*, *W. praehelvetica*, *Helvetoglobotruncana helvetica*, *Marginotruncana schneegansi*, *Dicarinella concavata*.

Remarks

As *Thalmanninella globotruncanoides* has been chosen as the marker of the base of the Cenomanian, it implies that the last *Stoliczkaia* ammonites -among which is the index of the zone, that is *Stoliczkaia* (*Shumarinaia*) *africana*- are not confined to the Albian (Vraconnian) but "climb" into the basal Cenomanian. For the two other limits of stages the planktonic foraminifers have no bioevents to serve as true markers. However, they can be used as "proxies": for example as regards the Cenomanian-Turonian boundary the first *Whiteinella praehelvetica* (very rare) with flattened chambers on the spiral side are already noted in the *Pseudaspidoceras pseudonodosoides* Zone of the uppermost Cenomanian, but at the Turonian-Coniacian limit there is no major extinction or appearance of foraminifera.

2 - Northwestern Europe

In the Paris-London Basin of the Boreal domain, the chalk sea was favourable to the development of keeled planktonic foraminifera only during the Cenomanian-Middle Turonian interval, that is in facies during which marl was also deposited. The installation of pure chalk facies starting in the Upper Turonian was no longer favourable (sea too shallow?) so only less informative globular forms are collected. From Upper Albian to Lower Turonian the zones are identical to those of the Tethyan domain, although the keels of the morphotypes are weakly developed.

Remark: there appears to be a slight diachronism of the *Thalmanninella reicheli* Zone (apparently younger in Tunisia, unless the ammonites are responsible?).

In return, the benthic foraminifera are often much more numerous and, starting in the Middle Turonian, it is with them that a biostratigraphic zonation can be made, up to the higher levels of the Santonian (the Boulonnais, ROBASZYNSKI & AMÉDRO, 2001) and up to the Campanian-Maastrichtian (Kent).

Conclusions

- A comparison of the ammonite zones of the Boreal and Tethyan domains shows numerous affinities between the two domains: almost two-thirds are the same.

- In Tunisia, nearly a third of the zones are based on species with North American affinities, so constitute excellent guides for intercontinental correlation.

- Planktonic foraminifera have only a third of the number of zones provided by ammonites. This disadvantage is compensated for by the fact that foraminiferal zones are global and that they can be recognized in the subsurface, in wells for example.

Acknowledgments

Our thanks to Bertrand MATRION of the Association Géologique Auboise for his skillful preparation of the table, to the two reviewers, Philippe COURVILLE and Jean-Pierre BELLIER, whose remarks led to improvements in the draft and of course to Nestor SANDER for the English version.

Bibliographic references

AMÉDRO F. (1992).- L'Albien du bassin anglo-parisien : Ammonites, zonation phylétique, séquences.- *Bulletin des Centres de Recherches Exploration-Production elf-aquitaine*, Pau, vol. 16, n° 1, p. 187-233.

AMÉDRO F. (2002).- Plaidoyer pour un étage Vraconnien entre l'Albien *sensu stricto* et le Cénomanien (système Crétacé).- *Académie Royale de Belgique*, *Mémoire*, Bruxelles, (Classe des Sciences), t. IV, 128 p., 9 pls.

AMÉDRO F. (2008).- Support for a Vraconnian Stage between the Albian sensu stricto and the Cenomanian (Cretaceous System).- *Carnets de Géologie / Notebooks on Geology*, Brest, Memoir 2008/02 (CG2008_M02), 83 p., 9 pls.

AMÉDRO F., ACCARIE H. & ROBASZYNSKI F. (2005).- Position de la limite Cénomanien-Turonien dans la Formation Bahloul de Tunisie centrale : apports intégrés des ammonites et des isotopes du carbone (δ13 C).- *Eclogae Geologicae Helvetiae*, Basel, vol. 98, p. 151-

167.

AMÉDRO F. & ROBASZYNSKI F. (2001a).- Les craies cénomaniennes du Cap Blanc-Nez (France) au regard de la stratigraphie événementielle. Extension de niveaux-repères du bassin anglo-parisien (Boulonnais, Kent, Normandie) à l'Allemagne du Nord.- *Bulletin de la Société Géologique de Normandie et des Amis du Muséum du Havre*, vol. 87, p. 9-29.

AMÉDRO F. & ROBASZYNSKI F. (2001b).- Les craies turoniennes du Boulonnais (France) au regard de la stratigraphie événementielle. Comparaison avec le Kent (UK) et la Normandie.- *Bulletin de la Société Géologique de Normandie et des Amis du Muséum du Havre*, vol. 87, p. 31-49.

BOLLI H.M. (1966).- Zonation of the Cretaceous to Pliocene marine sediments based on planktonic foraminifera.- *Asociación Venezolana de Geología, Minería y Petróleo, Boletín Informativo*, Chacao, vol. 9, p. 3-32.

CARON M., ROBASZYNSKI F., AMÉDRO F., BAUDIN F., DECONINCK J.-F., HOCHULI P., SALIS-PERCH NIELSEN K. von & TRIBOVILLARD N. (1999).- Estimation de la durée de l'événement anoxique global au passage Cénomanien / Turonien. Approche cyclostratigraphique dans la Formation Bahloul en Tunisie centrale.- *Bulletin de la Société géologique de France*, Paris, t. 170, n° 2, p. 145-160.

DUBOURDIEU G. (1956).- Étude géologique de la région de l'Ouenza (confins algéro-tunisiens).- *Service de la Carte géologique d'Algérie*, *Bulletin*, Alger, (Nouvelle Série), n° 10, 2 vols., 659 p.

GONZALEZ-DONOSO J.M., LINARES D. & ROBASZYNSKI F. (2007).- The rotaliporids, a polyphyletic group of Albian-Cenomanian planktonic for aminifera. Emendation of genera.- *Journal of Foraminiferal Research*, Washington D.C., vol. 37, p. 175-186.

KAPLAN U. & KENNEDY W.J. (1996).- Upper Turonian and Coniacian ammonite stratigraphy of Westphalia, NW Germany.- *Acta Geologica Polonica*, Warszawa, vol. 46, p. 305-352.

KENNEDY W.J., GALE A.S., LEES J.A. & CARON M. (1996).- The Global Boundary Stratotype Section and Point (GSSP) for the base of the Cenomanian stage, Mont Risou, Hautes-Alpes, France.- *Episodes*, Beijing, vol. 27, p. 21-32.

ODIN G.S. (1994).- Geological time scale (1994).- *Comptes Rendus de l'Académie des Sciences*, Paris, Sciences de la Terre, (II), t. 318, p. 59-71.

OGG J.G., AGTERBERG F.P. & GRADSTEIN F.M. (2004).- The Cretaceous Period. In GRADSTEIN F.M., OGG J.G. & SMITH A. Eds, Cambridge Univ. Press, 344-384.

PERVINQUIÈRE L. (1903).- Étude géologique de la Tunisie centrale.- Thèse, Faculté des Sciences de Paris, F.R. de Rudeval, Paris, 360 p.

PERVINQUIÈRE L. (1907).- Études de paléontologie tunisienne. 1. Céphalopodes des terrains secondaires.- Carte géologique de la Tunisie, F.R. de Rudeval, Paris, 438 p., 27 pls.

ROBASZYNSKI F. & AMÉDRO F. (2001).- Des nouveautés dans le Crétacé de la feuille de Marquise.- *Annales de la Société géologique du Nord*, Lille, (2ème série), t. 9, p. 25-38.

ROBASZYNSKI F., AMÉDRO F., GONZÁLEZ-DONOSO J.M. & LINARES D. (2007).- Les bioévénements de la limite Albien (Vraconnien)-Cénomanien aux marges nord et sud de la Téthys (S.E. de la France et Tunisie centrale). *In* : BULOT L.G., FERRY S. & GROSHENY D. (eds.), Relations entre les marges septentrionale et méridionale de la Téthys au Crétacé [*Relations between the northern and southern margins of the Tethys ocean during the Cretaceous period*].- *Carnets de Géologie / Notebooks on Geology*, Brest, Memoir 2007/02, Abstract 01 (CG2007_ M02/01), p. 3-15.

ROBASZYNSKI F. & CARON M. (coords.) et Groupe de travail européen des foraminifères planctoniques (1979).- Atlas de foraminifères planctoniques du Crétacé moyen (mer boréale et Téthys).- *Cahiers de Micropaléontologie*, Paris, fasc. 1 et 2, 185 + 181 p.

ROBASZYNSKI F. & CARON M. (1995).- Foraminifères planctoniques du Crétacé : Commentaire de la zonation Europe-Méditerranée.- *Bulletin de la Société géologique de France*, Paris, t. 166, n° 6, p. 681-692.

ROBASZYNSKI F., CARON M., DUPUIS C., AMÉDRO F., GONZÁLEZ DONOSO J.M., LINARES D., HARDENBOL J., GARTNER S., CALANDRA F. & DELOFFRE R. (1990).- A tentative integrated stratigraphy in the Turonian of Central Tunisia: Formations, zones and sequential stratigraphy in the Kalaat Senan area.- *Bulletin des Centres de Recherches Exploration-Production elf-aquitaine*, Pau, vol. 14, n° 1, p. 213-384, 44 pls.

ROBASZYNSKI F., CARON M., AMÉDRO F., DUPUIS C., HARDENBOL J., GONZÁLEZ DONOSO J.M., LINARES D. & GARTNER S. (1994).- Le Cénomanien de la région de Kalaat Senan (Tunisie centrale) : Litho-biostratigraphie et interprétation séquentielle.- *Revue de Paléobiologie*, Genève, vol. 12, n° 2, p. 351-505, 24 pls.

SIGAL J. (1987).- Une échelle zonale du Crétacé méditerranéen et quelques réflexions suscitées par son établissement, particulièrement à propos du Danien.- *Revue de Micropaléontologie*, Paris, vol. 30, n° 1, p. 32-51.