

(Foyer: sessions 4 & 5; Thursday pm)

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CENOMANIAN LARGER BENTHIC FORAMINIFERA AND THEIR **BIOSTRATIGRAPHIC UTILITY**

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SUMMARY

Despite forming a distinctive, diverse and often abundant element of the preserved fossil assemblages of mid-Cretaceous Neotethyan and central American carbonate platforms, there is no generally accepted and well-defined bioevent/biozonation scheme for larger benthic foraminifera (LBF), which limits their utility as biostratigraphic tools. To achieve this requires, in turn, a review of the identity of the taxa involved and a critical review of published reports of their stratigraphic ranges.

We have reviewed, and are reviewing, the published occurrences of over 150 taxa to establish their stratigraphic ranges. Once misidentifications are discounted, it is apparent that the inceptions and extinctions of some taxa (e.g., the alveolinids) provides a useful basis for recognising Cenomanian substages and occasionally events at higher resolution. Endemic forms and facies control on stratigraphic distribution means that the choice and timing of some key bioevents differs between regions within the Neotethyan - central American realm.

Intriguingly, some taxa are truly long-ranging and survive the end-Cenomanian extinction event, sometimes reappearing after an apparent absence of several million years. The reasons for this remain unknown but may include survival in refugia or homeomorphy of forms well-adapted to specific environmental niches. In summary, we present a draft biozonation for Cenomanian LBF, calibrated where possible to other fossil groups and the carbon isotope chronostratigraphic proxy, thereby increasing the biostratigraphic utility of this important fossil group.

RATIONALE

Forty years ago, in collaboration with many international experts, Rolf Schroeder (Frankfurt) and Madeleine Neumann (Paris) co-ordinated a Herculean effort to document and collate the records and distribution (in time and space) of what we call "larger benthic foraminifera" (LBF) from the mid Cretaceous period. They identified 56 taxa (species) from the Albian, Cenomanian and Turonian stages. Their work focussed in and around the Mediterranean region, from where the vast majority of their source material came. Despite this monumental work, Schroeder & Neumann (1985) did not use their range data to construct a *biozonation scheme* based on LBF. Quite correctly, they suggested that the high level of facies dependence displayed by many LBF would not easily translate into chronostratigraphically-calibrated biozones, correlatable over large distances. Additionally many sections where LBF are common, lack deeper-water fossils that afford better long-distance correlation and, more importantly, age-calibration.

Moreover, they also recognised that, for many LBF subgroups (e.g. at genus & family level) there was still insufficient knowledge of the precise taxonomic identity of the species therein. In other words, how can index fossils be recognised correctly if we cannot agree on how they should be recognised? (continued right)...

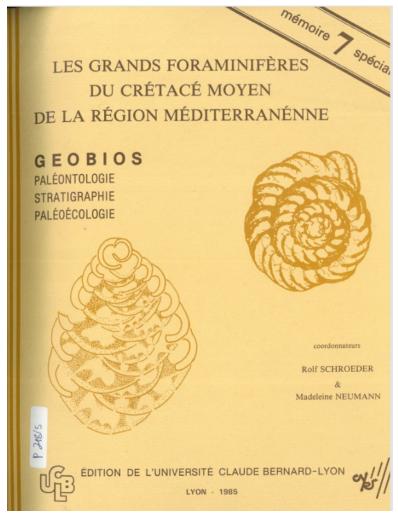
WORKFLOW



Assessment and grading of identity. Is the specimen the species it is supposed to be? If not, what should it labelled as?

Assessment and grading of age-calibration. Is the age attributed to the specimen/locality reasonable?

Is the age corroborated by other fossil groups? Is there independent calibration such as isotope data?



The milestone 1985 publication by Schroeder & Neumann which collated known occurrence data of mid-Cretaceous LBF and provided useful identity information on many of the taxa then known. Several taxonomic groups were not included because not enough was known about them - particularly their identity criteria.

Results already published: Bidgood et al., 2024 (Orbitolina)

Chronostratigraphy and Tethyan ammonite

zones (GTS2020; Gradstein et al., 2020)

Fagesia catinus

Neocardioceras juddii

alycoceras guerange

hotomagense

inerme

Mantelliceras dixon

Mantelliceras mantelli

perinflatum rostratum

Dipoloceras cristatur

ESTABLISH CONCISE IDENTITY CRITERIA

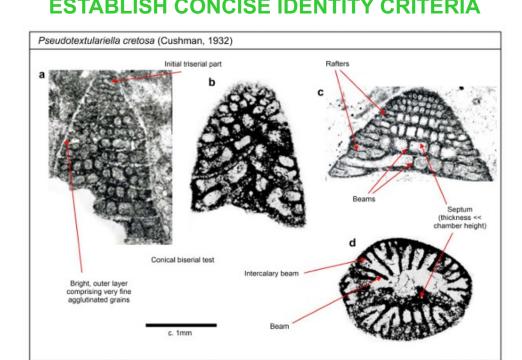


Fig. 18. Representative illustrations of Pseudotextulariella cretosa: a. Axial section. Bucur & Baltres (2002, pl. 3, fig.

Simmons et al., 2024 (the Nezzazatoidea)

GTS2020 (+Tethyan Ammonites & δ¹³C curve)

rhotomagense

inerme

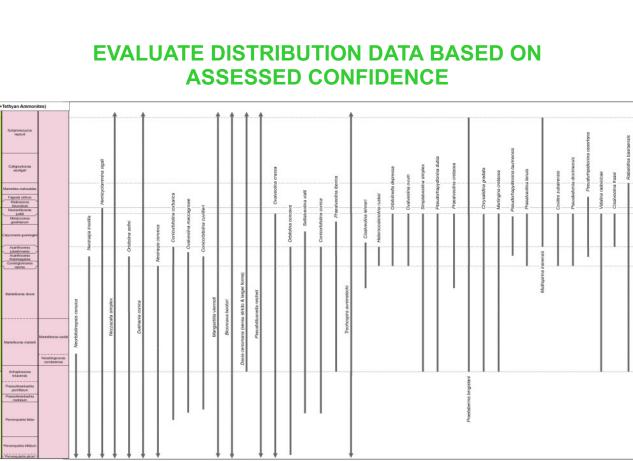
ntelliceras dixe

		1, Romania); b. Near axi	al section, Brönnimann (1966,	ella cretosa: a. Axial section, Bu pl. 3, fig. 1, southern England) ransversal section, Brönnimann	; c. Oblique tangential section
n exhaustive assessn		ture, except P. rugosa and	P. sarvakensis as discussed herein	stimates of stratigraphic ranges of the n. They have been assessed only fro	
CHARACTERISTIC	PSEUDOCYCLAMMINA LITUUS	PSEUDOCYCLAMMINA RUGOSA	PSEUDOCYCLAMMINA SARVAKENSIS	PSEUDOCYCLAMMINA SPHAEROIDEA	PSEUDOCYCLAMMINA MASSILIENSIS
Original description & provenance	As Cyclammina lituus; Yokoyama (1890), Tithonian-Berriasian, Japan	As Lituola rugosa; d'Orbigny (1850), Cenomanian, France	Schlagintweit & Yazdi-Moghadam (2023 ☼), Cenomanian, Iranian Zagros	Gendrot (1968), late Santonian, France	Maync (1959 ☼), Santonian, France
Basic image (reference source of image shown thus \$\pi\$)					
Other significant illustrative descriptions	Maync (1959 ☼); Kaever (1967); Hottinger (1967); Gušić (1975); Kobayashi & Vuks (2006)	Maync (1952 ☼, 1959)	N/A	Chiocchini et al. (2012); Albrich et al. (2015 ☼); Frijia et al. (2015); Arriaga et al. (2016)	Boix et al. (2011)
Wall	Agglutinated, alveolar	Agglutinated, alveolar	Agglutinated, alveolar	Agglutinated, alveolar (labyrinthic)	Agglutinated, alveolar
Overall shape	Axially compressed, often uncoiling	Axially compressed, often uncoiling	Subspherical, moderately compressed axially, no uncoiling observed	Subspherical, slightly compressed axially, flaring but only occasionally uncoiling	Axially compressed, often uncoiling
Dimensions (mm) (De = diameter equatorial; Da = diameter axial; Dp = diameter proloculus)	De = 1.0-2.7 (*sometimes 3.5+) Da = 0.8-1.8 Dp = 0.24-0.26	De = 3.1-4.3 Da = 0.7-2.3	De = 1.35 Dp = 0.11-0.30	De = 0.60-1.1 ** Da = 0.40-0.42 Dp = 0.10	De = 1.2-2.3 Da = 0.4-0.8
Chambers per whorl (first whorl = W ₁ , second whorl = W ₂ etc.)	W _F = 7-12 c. 3 uncoiled	W _F = 5-7 c. 2-3 uncoiled	W _F = 14-16	W _F = 10-12 in smaller forms, 13-14 in larger forms ** c, 1-2 uncoiled	$W_F = 5-7$ 2-3 uncoiled
No. of whorls	c. 2.5-3.5	c. 2	c. 2.5-3.5	c. 2.5-3.0 **	c. 1.5-2
Foramina diameter (µm)	50		20-35		
Stratigraphic Range (see caption)	Oxfordian – Aptian (Gušić, 1975; Bassoullet, 1997)	Albian – Cenomanian	Middle – late Cenomanian	Turonlan – Campanian (Velić, 2007; Albrich et al., 2015; Arriaga et al., 2016; Solak et al., 2020)	Middle Coniacian – Campanian (Velić, 2007; Boix et al., 2011; Schlagintweit & Yazdi-Moghadam, 2023)
Commens	(*) = Whittaker et al. (1998)			Note: Not the same as the similarly named Pseudocyclammina sphaeroidalis Hottinger, 1967 from the Late Jurassic of Morocco (**) Albrich et al. (2015)	

BUILD SYNONYMY/CHRESONYMY LISTS

? 1964 Pseudocyclammina hedbergi – Bozorgnia & 1988 Everticyclammina hedbergi – Sartorio & Venturini, Banafti, pl. 72, fig. 2; pl. 83, fig. 2; Aptian-Albian, p. 92, lower fig.; Neocomian (total range given as Berriasian-early Cenomanian), Italy. 1987 Buccicrenata subgoodlandensis - Loeblich & Hamaoui, p. 19, pl. 1, fig. 11; pl. 5, figs. 6-8; pl. 10, fig. Tappan, p. 99, pl. 96, figs. 1-9; Albian, Oklahoma, USA 1965 Pseudocyclammina hedbergi - Gollesstaneh, p. Harithi, p. 603, pl. 2, figs. 1-2; pl. 3, fig. 7; pl. 4, figs. 16-130-132, pl. 3, figs. 1-4; Valanginian - Aptian; Iranian 18; Cenomanian (total range given as Albian Cenomanian), Jordan. 1966 Buccicrenata libyca n. sp. – Gohrbandt, p. 67, pl. 1, 1990 Buccicrenata hedbergi – Simmons, p. 84, pls. 3.25figs. 11-16; middle – late Cenomanian, Libya. 3.28; Valanginian-Aptian (and described as ranging into 1966 Pseudocyclammina aff. hedbergi - Banner, pl. 3, the Cenomanian), Oman Mountains. figs. 5a-5b; early Cenomanian, offshore Abu Dhabi. [fide 1991 Buccicrenata hedbergi - Schlagintweit, pl. 10, figs. Banner & Highton, 1990] 1-4; late Aptian, Austrian Alps. 1967 Pseudocyclammina cf. rugosa - Arkin & Hamaoui, ? 1992 Buccicrenata hedbergi - Granier, pl. 2, fig. 2; pl. 2, fig. 3; Cenomanian, Israel. Barremian – early Aptian, Senegal [alveolar wall not 1969 Pseudocyclammina rugosa - Sampò, pl. 39, figs. 6- clear]. Albian, Iranian Zagros. 1970 Pseudocyclammina aff. hedbergi - Banner, pl. 5, Banner & Highton, 1990). Cenomanian, Serbia. ? 1974 Pseudocyclammina cf. rugosa - Moullade & [wall appears to be simple, non-alveolar] Peybernès, pl. 3, figs. 2, 5; late Albian, Spain. pl. 5, fig. 2; pl. 6, figs. 3-4; pl. 7, figs. 1-3; pl. 8, figs. 1-5; Pacific Ocean [alveolar wall not clear]. comm., 1987)), Croatia. 1976 Pseudocyclammina rugosa - Kalantari, pl. 10, figs. species]. 13-14; Aptian, Iranian Zagros. 1976 Pseudocyclammina cf. rugosa - Kalantari, pl. 22, 146, fig. 5b-c; early Cenomanian, Egypt. figs. 17-18, 25; Cenomanian, Iranian Zagros. 1978 Pseudocyclammina hedbergi – Berthou & Pantoja-Alor, p. 69, fig. 6 (1-2); early Aptian, Mexico. Schroeder, pl. 8, figs. 3-5; late Albian, Portugal. 1980 Everticyclammina hedbergi - Arnaud-Vanneau, p. 4D, E; middle-late Albian, Honduras. Decrouez, pl. 5, figs. 1-2; early Aptian, Türkiye [alveolar pl. 1, figs. 3-4; middle Albian, Venezuela. ? 1984 Everticyclammina hedbergi - Chiocchini et al., pl. figs. 8-9; late Aptian, Switzerland. Albian], Texas, USA. pl. 10.5, fig. 1; Albian, Oman Mountains. figs. 2-3; Valanginian – Hauterivian, Oman Mountains. unlikelyl. 10.5, fig. 4; Cenomanian, Oman Mountains [one of us pl. 1, fig. 34; Cenomanian, Sinai, Egypt. (FS) has also seen similar material from the middle Cenomanian of Oman (unpublished data)].

1994 Buccicrenata hedbergi - Simmons, pl. 9.4, fig. 2; Valanginian – ?Hauterivian, Oman Mountains. figs. 7-7a; early Cenomanian, offshore Abu Dhabi. [fide 1994 Pseudocyclammina lituus - Shakib, pl. 7.3, fig. 6; Hauterivian, Iranian Zagros. 1974 Pseudocyclammina rugosa - Radoičić, pl. 5, figs. 1- Non 1994 Pseudocyclammina hedbergi - Bodrogi et al., pl. 12, fig. 17; pl. 13, fig. 1; Early Cretaceous, Hungary ? 1995 Buccicrenata hedbergi - Arnaud-Vanneau & 1975 Everticyclammina virguliana (Koechlin) - Gušić, Sliter, p. 550, pl. 1, fig. 5; ?late Aptian-early Albian, midpl. 9, figs. 1-5; pl. 10, figs. 2,4; "late Aptian - early Non 1997 Ammobaculites subgoodlandensis - Ismail & Albian" (now thought to be late Aptian (Gušić, pers. Soliman, p. 166, pl. 1, fig. 5; Coniacian, Egypt ? 1997 Buccicrenata subgoodlandensis - Ayyad et al., p. 1999 Pseudocyclammina hedbergi - Scott & Finch, fig. 489, fig. 178; pl. 40, fig. 5; pl. 63, figs. 3-4; pl. 65, fig. 1; 2001 Buccicrenata subgoodlandensis - BouDagherearly Aptian (total range given as Barremian - early Fadel, p. 168-169, pl. 1, figs. 5-7; Albian, Oklahoma, USA and early Cenomanian, offshore Abu Dhabi. ? 1982 Pseudocyclammina hedbergi – Altıner & 2001 Buccicrenata hedbergi – BouDagher-Fadel, p. 169, 2007 Everticyclammina hedbergi - Schroeder et al., pl. I, 1, fig. 20; early Aptian, Central Italy [alveolar wall not 2011 Buccicrenata subgoodlandensis - Filkorn & Scott, p. 185, fig. 4.7-4.8; late Albian, Mexico. 1985a Buccicrenata subgoodlandensis - Loeblich & Non 2011 Everticyclammina hedbergi - Roozbahani, pl. Tappan, p. 100, pl. 2, figs. 4-10; Early Cretaceous [= 1, fig. 1; Early Cretaceous, central Iran [possibly not a 1987 Buccicrenata subgoodlandensis - Simmons & Hart, Non 2013 Everticyclammina hedbergi (Gorbachik, 1968) (sic) - Nozaripour et al., pl. 1, fig. 4; Albian-1987 Buccicrenata hedbergi - Simmons & Hart, pl. 10.4, Cenomanian, Iranian Zagros [indeterminate, but very ? 1987 Buccicrenata? rugosa - Simmons & Hart, pl. ? 2013 Buccicrenata libyca Gohrbandt - Shahin & Elbaz,



Above: range chart of selected taxa based on uncritical analysis of the literature Below: range chart of the same taxa after critical evaluation

RATIONALE (...ctd.)

In the four decades since Schroeder & Neumann's work, the amount of additional, available literature has more than trebled and records have extended virtually across the globe to include the Americo-Caribbean region, the broader Middle East region, East Africa, the Subcontinent and the Far East Many new species have been described, both from these "new" areas and from in and around the "classic" Mediterranean. This big increase in data (1,000+ references) has, however, come with a price. Many records of LBF from rock sections in many places are based on poorly identified specimens and/or poorly age-calibrated section intervals. In an early canvass of new data, we estimated as many as a half of all data points in the recent literature were based on material whose identity (if specimens were actually illustrated at all) was questionable at best. In parallel, we also found that many age labels attributed to sections and their LBF specimens, were uncorroborated by actual independent evidence or was the result of circular reasoning. Such "loose" treatment of identity and age-calibration results in LBF ranges which can be considerably extended from the species' true range. Such information dilutes the effectiveness of any fossil as a biostratigraphic indicator and has repercussions for other studies based on the same, erroneous data, such as paleoenvironmental reconstructions and evolutionary

Our work has involved a thorough review of the literature in a workflow (left) which will eventually result in the treatment of six major Cenomanian LBF subgroups which, in total, amount to more than 150 species. The results for two subgroups have already been published, building on general work by Simmons & Bidgood (2023); on the Nezzazatoidea (Simmons et al., 2024) and the Loftusiida (Simmons et al., 2025) and a third, smaller paper has concentrated on the genus Orbitolina sensu stricto (Bidgood et al., 2024). Current work is focussed on the Alveolinoid Superfamily and the Orbitolinid Suborder (to be published hopefully later this year) with work on the final groups - the Soritoid Superfamily and 'Miscellaneous' Taxa - to begin later this year. A seventh part will produce a synthesis of the work into a biozonation scheme for Cenomanian LBF, with further discussions on paleobiogeography of the whole group and observations on evolution and extinction patters and mechanisms.

Anecdotally, informal experiments with publically-available literature and Al/LLM to try and establish consistent identity and confident biostratigraphy for individual species has provided answers which are too 'vague' to be of any real value other than just a relatively simple approximate 'guide' and certainly not at the level of detail required to establish accurate biostratigraphic interpretations. This is partly due to inconsistencies/errors in the published data, and deficiencies in the AI/LLM programs themselves. Our approach has been distinctly 'old school' - relying on assessments by subject-matter experts (SMEs) based on knowledge and experience.

Guide to the identification of key features in *Dicyclina* (a genus not treated by Schroeder & Neumann, 1985), by Simmons et al. (2025).

PRODUCTION OF CALIBRATED RANGE CHARTS AND ASSESSMENTS OF CONFIDENCE

Confident & common range confirmed by identity & age

Confident range confirmed by

Uncertain range based on unconfirmed identity & age.



Orbitolina taxa

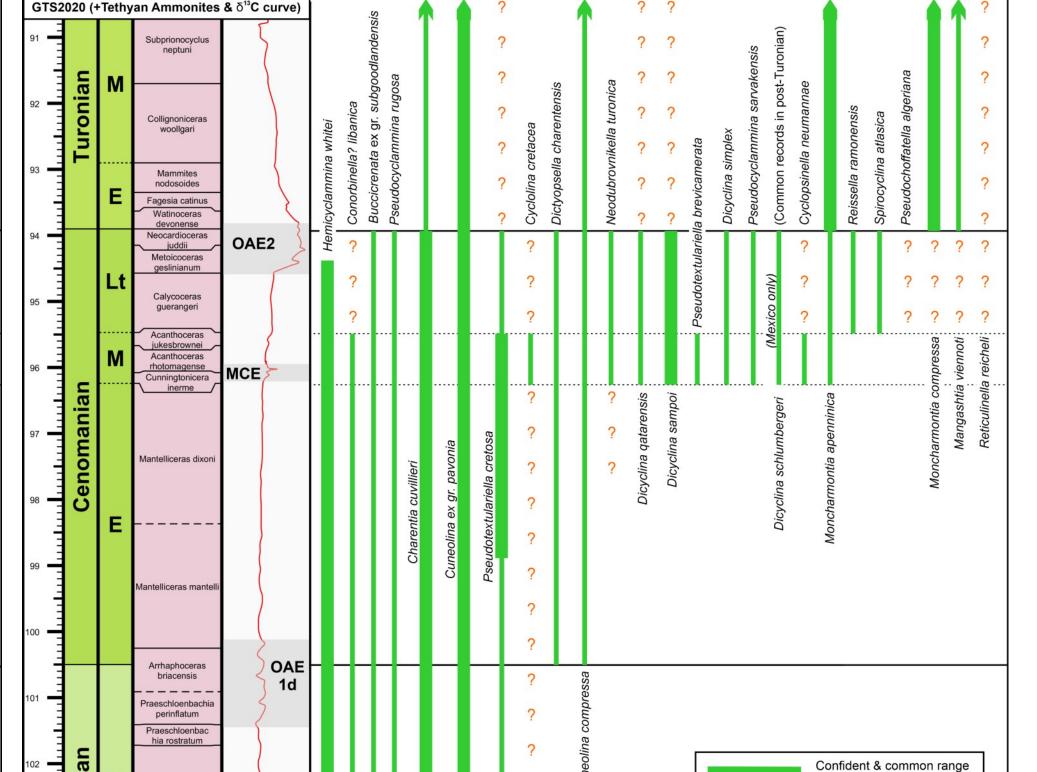
Confident & Common

Confident but Scarce





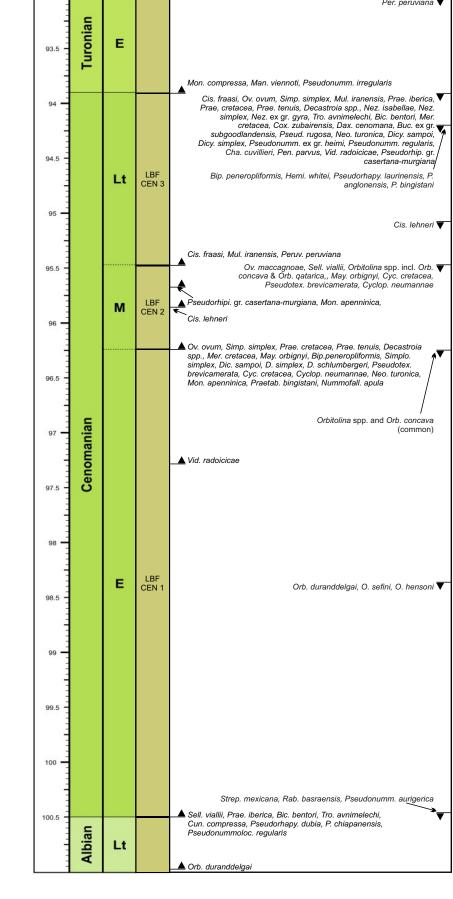
Simmons et al., 2025 (the Loftusiida)



Summary Bioevents & Biozonation (provisional, work in progress)

GTS 2020 Larger Benthic Foraminifera (Simmons & Bidgood, 2023; Bidgood et al., 2024

Simmons et al., 2024, 2025 and in prep.)



ACKNOWLEDGEMENTS

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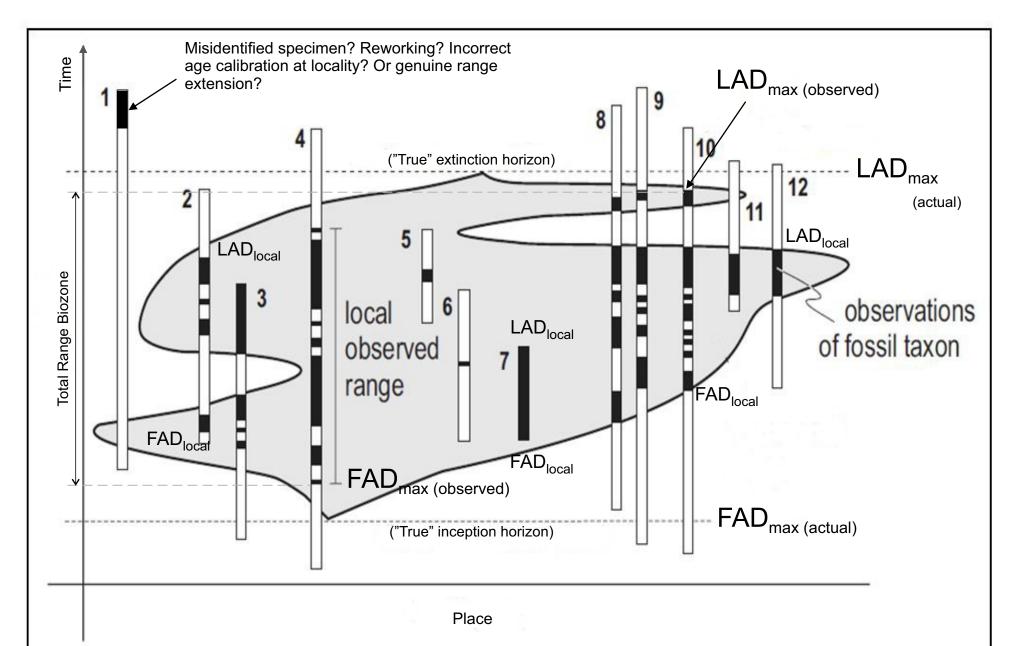
REFERENCES

References used in our study are far too numerous to list here. Nearly 1,200 references have been used (so far) herein to evaluate the range and distribution of Cenomanian LBF (see bibliographies in, for example, Bidgood et al., 2024 and Simmons et al., 2024, 2025).

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- Simmons, M.D., Bidgood, M.D., Consorti, L. & Schlagintweit, F., 2024. Review of the identity and biostratigraphy of Cenomanian "Larger" Benthic Foraminifera: Part 1 the Nezzazatoidea. Acta Palaeontologica Romaniae, 21 (1): 5-57. • Simmons, M.D., Bidgood, M.D., Consorti, L. & Schlagintweit, F., 2025. Review of the identity and biostratigraphy of Cenomanian "Larger" Benthic Foraminifera: Part 2 - the Loftusiida. Acta Palaeontologica Romaniae, 21 (1): 103-192.



Scan here to go to our Cenomanian Projects website where papers written by us on Cenomanian LBF can be downloaded.



confirmed by identity & age

Confident range confirmed by identity or age calibration

Uncertain range based on

unconfirmed identity & age

This diagram shows the challenges when assessing the distribution of fossil species in space and time. The challenge is particularly acute when dealing with LBF because of the group's sometimes narrow restriction to a discrete environmental biofacies. Cross-calibration provided by other fossil types which are facies-indepedent (e.g., planktonic forams, nannofossils, ammonites) is difficult as the two groups are seldom found together in the same rocks. (Diagram after Pearson (1998) and Sadler (2010) with modifications).