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# Unique microgastropod biofacies in the Early Triassic: Indicator of long-term biotic stress and the pattern of biotic recovery after the end-Permian mass extinction

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## Abstract

Microgastropod-dominated shell beds formed during the aftermath of the end-Permian mass extinction comprise a characteristic Early Triassic biofacies. The identification of this biofacies is significant: (1) no other episode in the geologic record is characterized by the lack of larger gastropods and abundant, conspicuous microgastropod-dominated shell beds; (2) its distribution indicates that the recovery from the end-Permian mass extinction was regionally variable and began sooner than previously interpreted. Occurrence of this biofacies supports the contention that chemically and/or physiologically harsh environmental conditions related to the cause of the end-Permian mass extinction were prolonged through much of the Early Triassic. **To cite this article: M. Fraiser et al., C. R. Palevol 4 (2005).**

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## Résumé

**Un biofaciès exceptionnel à microgastéropodes du début du Trias : un indicateur d'un stress biologique prolongé et des modalités de la reconquête biologique après les extinctions en masse de la fin du Permien.** Aux extinctions massives de la fin du Permien succède, au début du Trias, un biofaciès caractéristique de bancs coquilliers essentiellement édifiés par des microgastéropodes. L'identification de ce biofaciès est importante, car : (1) aucune autre période des annales géologiques n'est caractérisée à la fois par l'absence de grands gastéropodes et l'abondance notable de bancs coquilliers essentiellement édifiés par des microgastéropodes ; (2) leur distribution indique que la reconquête biologique succédant à la crise de la fin du Permien différait selon les régions et débutait plus précocement qu'il n'était admis jusqu'à présent. L'existence de ce biofaciès conforte l'opinion selon laquelle des conditions environnementales sévères, chimiques et/ou physiologiques, auxquelles on attribue la crise biologique de la fin du Permien, persistent au cours d'une grande partie du début du Trias.

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*Mots clés :* Microgastéropodes ; Début du Trias ; Crise biologique de la fin du Permien ; Reconquête biologique ; Biofaciès ; Opportunisme

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## 1. Introduction

Fossil accumulations with distinct characteristics that recur throughout a stratigraphic unit are commonly denoted as a ‘biofacies’ and have broad paleoecological and paleobiological implications (e.g., [16]). A variety of evolutionary, depositional and paleoenvironmental conditions have aided in creating conspicuous biofacies throughout the geologic record that are widespread and time-specific; well-known examples include the graptolite facies of the Lower Paleozoic (e.g., [6]), regional encrinites of the Paleozoic and Early Mesozoic [4], the Ammonitico Rosso of the Mesozoic (e.g., [3]), and the ‘*Lithiotis*’ facies of the Early Jurassic (e.g., [8]).

Densely packed accumulations of biologic hardparts, or shell beds (sensu [19]), have been particularly useful for determining stratigraphic, taxonomic, and paleoecologic patterns through the Phanerozoic on broad and fine scales [13,19,21] and play a major role in defining biofacies. Lower Triassic shell beds have been the subjects of recent studies because of the information they yield regarding paleoenvironmental and paleoecological conditions during the aftermath of the end-Permian mass extinction (e.g., [7]). A recent quantitative paleoecological study of Lower Triassic shell beds in the western United States indicates that gastropods larger than 1 cm in height were extremely rare in shallow subtidal marine environments during the Early Triassic (comprising only 1% of the fauna), whereas microgastropods (adult gastropods that are < 1 cm in height) and juveniles were extremely abundant, commonly forming microgastropod-dominated shell beds [13]. These results reflect a global phenomenon of frequently recurring microgastropod-dominated shell beds during the Early Triassic; for example, in Lower Triassic strata deposited throughout western Paleotethys, microgastropod-dominated shell beds are so conspicuous and common that they have been informally named and referred to in the literature as ‘Gastropoden-Oolith’ and ‘oolite a gasteropodi’ (e.g., [2,9]). Furthermore, gastropod diversity is very low during the Early Triassic [27]. These previous observations on the

ubiquity of microgastropod-dominated shell beds may indicate that they comprise a unique, global Lower Triassic biofacies with significant implications for paleoenvironmental conditions and the pattern of recovery following the end-Permian mass extinction that have not previously been recognized. This study was undertaken to characterize the occurrences of Lower Triassic microgastropod-dominated shell beds, and to evaluate the paleoecological and paleoenvironmental significance of this biofacies for one of the most critical intervals in the history of life.

## 2. Geologic setting and methods

Shell beds in Lower Triassic strata exposed in eastern Greenland, northern Italy, Japan (Kyushu, Shikoku and Miyagi-ken), central and northern Oman and the western USA, as well as from a core in western Australia, were the focus of the field studies (Fig. 1). Strata representing shallow marine subtidal to slope deposition and continuous accumulation on open-ocean seamounts in all oceans throughout the 5–6 Myr before the biotic recovery [25,26] were examined (Fig. 1). A semi-quantitative scoring system was employed to determine the abundance of microgastropods and microgastropod-dominated shell beds in Lower Triassic members or formations: a score of ‘0’ indicates microgastropods were absent; ‘1’ indicates microgastropods were present but not as rock-forming or dominant components of packstones or grainstones (i.e., wackestones or present with other numerically dominant fossils); ‘2’ was assigned when the microgastropod-dominated shell beds were present but rare or sporadic; ‘3’ was assigned when microgastropod-dominated shell beds were common to abundant. Microgastropod-dominated shell beds are packstones and grainstones in which microgastropods comprise 60% or more of the bioclasts (sensu [13]). Bulk samples of microgastropod-dominated shell beds were collected from the field and the samples were disaggregated in the laboratory so that fossils could be identified and tallied; petrographic sections also were made

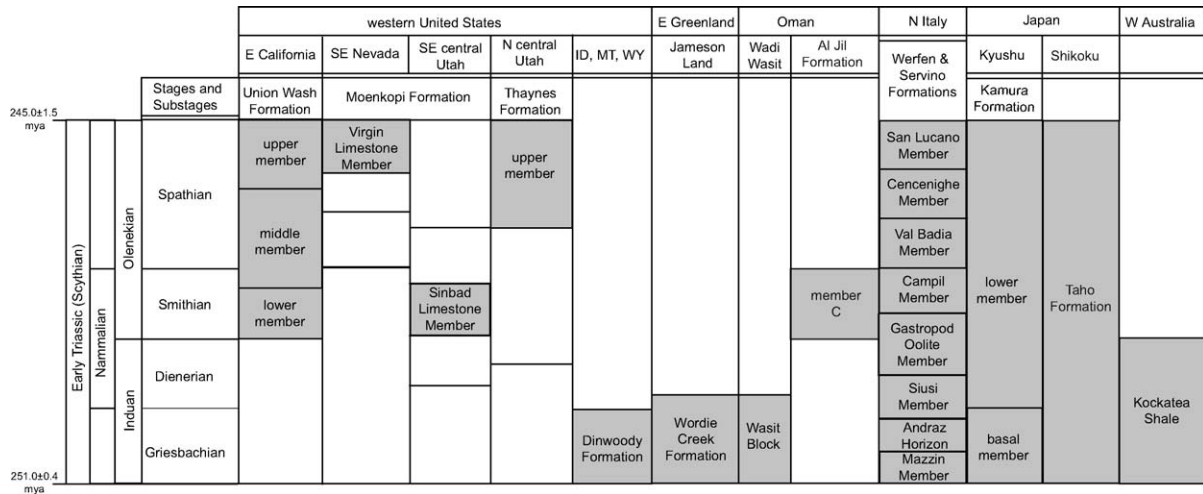


Fig. 1. Generalized stratigraphy of Lower Triassic strata examined in the field or in core in the western United States, eastern Greenland, central and northern Oman, northern Italy, southern Japan, and western Australia [15,22,25,26,30,32,36–39].

Fig. 1. Tableau stratigraphique synthétique des niveaux du Trias inférieur étudiés à l’affleurement ou sur carottes dans l’Ouest des États-Unis, l’Est du Groenland, le centre et le Nord de l’Oman, le Nord de l’Italie, le Sud du Japon et l’Ouest de l’Australie [15,22,25,26,30,32,36–39].

and examined. The field and laboratory portions of this research were supplemented by an extensive literature search to determine the pattern of occurrence of other microgastropod-dominated shell beds in Lower Triassic strata not examined in the field portion of this study.

### 3. Lower Triassic microgastropod-dominated shell beds

In shallow marine subtidal to distal shelf environments, Lower Triassic microgastropod-dominated shell beds typically range from 2 to 15 cm in thickness and are loosely-densely to densely packed (sensu [20], Fig. 2). The microgastropod-dominated shell beds are parautochthonous, were deposited subtidally by regular wave agitation or by storm processes, and are usually laterally continuous for meters to decameters (Fig. 2) – sedimentologic and taphonomic processes are discussed fully in [13,14]. These packstones and grainstones are commonly associated with ooids and are analogous to the ‘gastropod–oolites’ of previous authors. Early Triassic microgastropods are most commonly preserved as internal, external, and recrystallized molds, but silicified and partially silicified microgastropod faunas do exist (see [22] and unpublished field data). In Neotethys sections, microgastropod-dominated shell beds also are associated with oolites (see [1] and Baud, pers. commun.).

In open-ocean seamount accumulations, microgastropod-dominated shell beds are autochthonous to parautochthonous and are only a few millimeters to a few centimeters in thickness. In the basal member of the Kamura Formation (Fig. 1), microgastropod-dominated shell beds, peloids, and microbial crusts form triplets that repeat upsection in the basal member [32]. Microgastropod-dominated shell beds are abundant and typically overlie microbial crusts in sections from eastern Paleotethys, too [18,23].

In thin section and in outcrop it is apparent that microgastropods are the numerically dominant fossils in many shell beds (Fig. 2A and B). Bulk samples of microgastropod-dominated shell beds contain hundreds of microgastropods and commonly other fossils are very rare or absent (Table 1). *Naticopsis*, *Omphaloptycha*, and *Cylindrobullina* are the most common gastropod genera in the study areas (e.g., [5,13]).

The results from the field- and literature-based scoring reveal that microgastropods and microgastropod-shell beds were present in variable amounts in different oceans during all stages and substages of the Early Triassic (Fig. 3; Table 2). While no member received a score of 0, microgastropod-dominated shell beds are abundant (score of 3) in low latitudes primarily in Paleotethys, Neotethys, eastern Panthalassa, and open-ocean Panthalassa (Fig. 4; Table 2). In the members and formations scored as 3, microgastropod-dominated

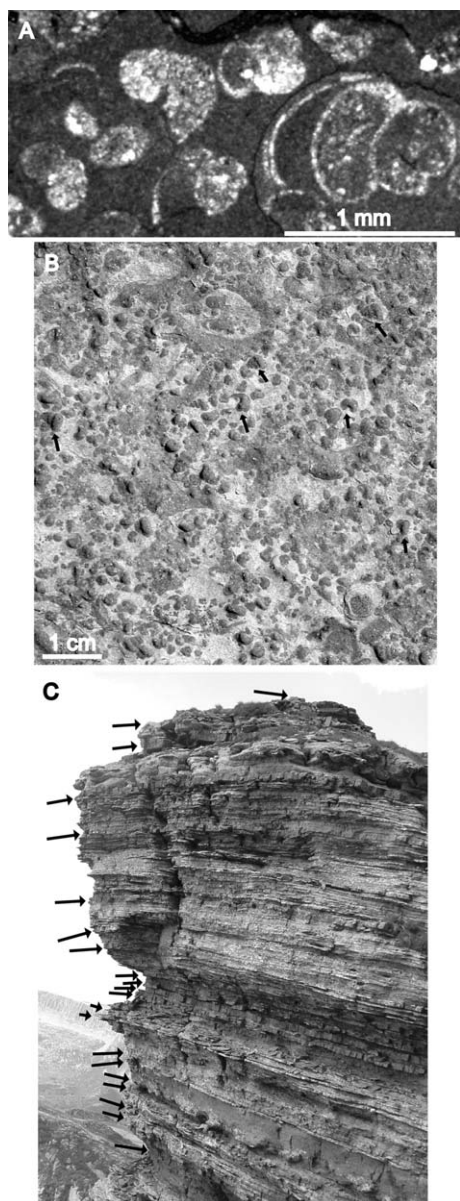


Fig. 2. Lower Triassic microgastropod-dominated shell beds from the Gastropod Oolite Member, Werfen Formation, Punta Rolle, Italy. (A) Petrographic section showing cross- and longitudinal sections of 12 microgastropods. (B) Hand sample; arrows point to microgastropods that can be discerned with the naked eye. (C) Arrows point to recurring microgastropod-dominated shell beds in approximately 15 m of strata. This member was scored as a '3'.

Fig. 2. Bancs coquilliers contenant essentiellement des microgastéropodes du *Gastropod Oolite Member*, formation de Werfen, Punta Rolle, Italie. (A) Lame mince montrant des sections transversales et longitudinales de 12 microgastéropodes. (B) Échantillon de poche ; les flèches indiquent des microgastéropodes visibles à l'œil nu. (C)

shell beds occur repeatedly upsection for many meters and are an easily recognizable feature (Fig. 2C); nearly half of all shell beds in some stratigraphic sections have been identified as microgastropod-dominated shell beds (Table 3).

#### 4. Discussion and conclusions

The paleontologic and sedimentologic characteristics, frequency, and global distribution of Lower Triassic microgastropod-dominated shell beds indicate that they comprise an extensive microgastropod biofacies during the aftermath of the end-Permian mass extinction. Microgastropod-dominated faunas and shell beds have occurred at other times in the Phanerozoic, but typically they were restricted to physically and chemically harsh environments that were limited spatially and temporally and existed contemporaneously with other paleocommunities containing larger gastropods and normal marine faunas [see references in 13]. Thus, the Lower Triassic microgastropod biofacies is particularly characteristic of the Lower Triassic. Although bivalves are actually the most abundant fossils in Lower Triassic strata [13], they are also ubiquitous throughout the entire post-Paleozoic and therefore do not comprise a biofacies unique to the Early Triassic.

The most significant aspects of the extensive Lower Triassic microgastropod biofacies lie in the pattern of biotic recovery it elucidates and in the paleoenvironmental conditions it reflects during the aftermath of the end-Permian mass extinction. Following the end-Permian mass extinction, microgastropods flourished throughout the world's oceans due to their opportunistic behavior in different oceans at different times, as discussed in Fraiser and Bottjer [13]. This proliferation of small gastropods promoted the deposition of a long-lasting, global and distinctive microgastropod biofacies. The presence of the microgastropod biofacies in varying abundances during different stages and sub-stages in different oceans is further evidence that the recovery from the end-Permian mass extinction was regionally variable (cf. [40,41] and Fig. 4). Furthermore, only two of the uppermost Lower Triassic (Spathian) rock units studied was given a score of 3 (the lower Spathian Val Badia Member, Servino Formation, and the Calcaires en Petits Bancs, Khaneh Kat Formation) despite many sample points (Fig. 4;



Table 1

Numbers of microgastropods and other fossils tallied from 10 bulk samples of microgastropod-dominated shell beds. **I**: Induan; **N**: Nammalian; **Sm**: Smithian; **Sp**: Spathian. Tallies for samples from the Siusi, Gastropod Oolite, and Campil Members of the Werfen Formation were obtained by leaching and extracting fossils from ~2,500 cm<sup>3</sup> of material immersed in buffered acid; tallies for the Sinbad Limestone Member, Moenkopi Formation and for the upper member, Thaynes Formation were obtained by mechanical disaggregation of bulk samples 27,200 cm<sup>3</sup> in size. Tableau 1. Dénombrement des microgastéropodes et d'autres fossiles d'après 10 échantillonnages effectués dans des bancs coquilliers essentiellement édifiés par des microgastéropodes. **I** : Indusien ; **N** : Nammalien ; **Sm** : Smithien ; **Sp** : Spathien. Les comptages dans les échantillons provenant des membres Siusi, Gastropod Oolite et Campil de la formation de Werfen ont été effectués après tamisage et extraction des fossiles d'environ 2500 cm<sup>3</sup> de roches immergées dans un tampon acide ; les comptages dans la Sinbad Limestone Member, la formation de Moenkopi et dans le membres supérieur de la formation de Thaynes ont été effectués après désagrégation mécanique d'échantillons correspondant à un volume de 27 200 cm<sup>3</sup>.

		micro-gastropods	bivalve individuals	conodonts	crinoids	echinoderm plates	echinoid spines	fish teeth	<i>Lingula</i>	serpulids
Sp	upper member	402	67	0	1	0	3	0	0	0
	(Thaynes Fm.)	93	47	0	0	0	0	0	1	0
Sm	Campil Member	436	0	12	0	0	0	0	3	0
N	Gastropod Oolite Mbr.	302	0	1	0	0	0	0	17	0
	Sinbad Limestone Mbr.	196	86	0	0	0	0	0	0	0
		99	10	0	0	0	0	0	0	0
I	Siusi Member	83	53	0	0	0	1	0	0	0
		179	14	0	0	0	0	0	73	0
		291	0	0	0	0	0	0	0	2
		114	61	0	0	3	0	1	0	0

Table 2), and the microgastropod biofacies is apparently completely absent in the Boreal Ocean (Fig. 4) (although there are fewer sample points in this region). Therefore, while larger gastropods were extremely rare in all oceans throughout much of the Early Triassic (gastropods larger than 1 cm in height are present in the Spathian Werfen Formation in northern Italy [28], and in the Griesbachian shallow settings of Oman [40]), rock-building densities (and opportunistic behavior) of microgastropods were prolific in low paleolatitudes, and the disappearance of the microgastropod biofacies was largely complete by the Spathian. Thus, the pattern of recovery from the end-Permian mass extinction in high latitudes appears to be different from the recovery in low latitudes, as previously suggested [41].

Also, it has been suggested previously that the recovery from the end-Permian mass extinction did not begin until the Middle Triassic (Anisian), when taxonomic diversity increased significantly [12]. However, the Lower Triassic microgastropod biofacies patterns presented here indicate that the recovery from the end-Permian mass extinction actually began sooner than the Middle Triassic. This supports conclusions of previous paleoecological studies on patterns of tiering [32,40]. Thus, results from this research indicate that ecologic and taxonomic diversity aspects of a recovery can be decoupled during the aftermaths of mass extinctions

(cf. [11]). Paleoecological studies must be employed to elucidate a complete picture of evolutionary patterns and processes, even during the aftermaths of mass extinctions; data on species richness are insufficient if used alone.

The distribution and abundance of the microgastropod biofacies is akin to other Early Triassic disaster forms and anachronistic facies (e.g., [31]) and likely formed for similar reasons. The close associations of microgastropods to microbialites in open-ocean Panthalassa and in eastern Paleotethys and to ooids in western Paleotethys and in eastern Panthalassa are indications that the nature of the recovery from the end-Permian mass extinction differed from ocean to ocean and that the interplay between metazoans, microbes, and the environment was complex. Furthermore, the frequency and global distribution of the Lower Triassic microgastropod biofacies and its association with these biosedimentological features provide paleoecological evidence indicating that chemically and/or physiologically harsh environmental conditions, possibly caused by marine anoxia (e.g., [17]), or a biocalcification crisis likely related to the cause of end-Permian mass extinction, were prolonged throughout the Early Triassic (cf. [24,29,42]) and that these conditions adversely affected the Earth's biota for several million years. The distribution of opportunists, biofacies, anachronistic

Table 2

Spatial and temporal occurrences of microgastropods and the microgastropod-dominated shell beds during the Early Triassic based on (A) field data and on (B) data obtained from the primary literature. See text for explanation of scoring. **G**: Griesbachian; **D**: Dienerian; **I**: Induan; **N**: Nammalian; **Sm**: Smithian; **Sp**: Spathian; **O**: Olenekian; **Sc**: Scythian (used when more precise age is not known). References for members and formations scored as 2 and 3 are included in the captions for Fig. 3; references for members and formations from the literature scored as 1 include: Sorkh Formation [10]; Bogdo Formation [34]; Csopak Marl Formation [9]

Tableau 2. Répartition dans l'espace et dans le temps des microgastéropodes et des bancs coquilliers essentiellement édifés par des microgastéropodes du début du Trias, d'après des observations faites sur le terrain (A) et les données des publications originales (B). Pour l'explication des repères, voir le texte. **G** : Griesbachien ; **D** : Diénérien ; **I** : Indusien ; **N** : Nammalien ; **Sm** : Smithien ; **Sp** : Spathien ; **O** : Olenekien ; **Sc** : Scythien (terme utilisé lorsqu'un âge plus précis est connu). Les références aux membres et aux formations répertoriées « 2 » et « 3 » sont incluses dans les légendes de la Fig. 3 ; les références aux membres et aux formations répertoriées « 1 », issues de la littérature, concernent les formations de Sorkh [10], de Bogdo [34] et de Csopak Marl [9].

	stage or substage	Lower Triassic Member or Formation	Early Triassic ocean	environment of deposition	score	
(A) this study	Sc	Taho Formation	open-ocean Panthalassa	shallow subtidal (seamount)	1	
	O	middle member, Union Wash Fm.	eastern Panthalassa	outer shelf/slope	1	
	Sp	Cencenighe Member, Werfen Fm.	western Paleotethys	shallow subtidal	2	
	Sp	San Lucano Member, Werfen Fm.	western Paleotethys	shallow subtidal	1	
	Sp	upper member, Union Wash Fm.	eastern Panthalassa	outer shelf/slope	1	
	Sp	upper limestone member, Thaynes Fm.	eastern Panthalassa	shallow subtidal	2	
	Sp	Virgin Limestone Member, Moenkopi Fm.	eastern Panthalassa	shallow subtidal-middle shelf	2	
	Sp	Val Badia Member, Servino Fm.	western Paleotethys	shallow subtidal	3	
	Sp	Val Badia Member, Werfen Fm.	western Paleotethys	shallow subtidal	2	
	Sm	Campil Member, Servino Fm.	western Paleotethys	shallow subtidal-middle shelf	3	
	Sm	Campil Member, Werfen Fm.	western Paleotethys	shallow subtidal-middle shelf	1	
	Sm	lower member, Union Wash Fm.	eastern Panthalassa	shallow subtidal	3	
	Sm	Hiraiso Formation	western Paleotethys	middle shelf	1	
	Sm	member C, Al Jil Formation	Neotethys	outer shelf/slope	1	
	N	Gastropod Oolite Member, Werfen Fm.	western Paleotethys	shallow subtidal	3	
	N	Sinbad Limestone Mbr., Moenkopi Fm.	eastern Panthalassa	shallow subtidal	3	
	I	Siusi Member, Werfen Fm.	western Paleotethys	shallow subtidal-middle shelf	3	
	I	Kockatea Shale	Neotethys	middle shelf	1	
	D	Gastropod Oolite Member, Servino Fm.	western Paleotethys	shallow subtidal	3	
	G	basal member, Kamura Fm.	open-ocean Panthalassa	shallow subtidal (seamount)	3	
	G	Dinwoody Formation	eastern Panthalassa	shallow subtidal-middle shelf	1	
	G	Mazzin Member, Werfen Fm.	western Paleotethys	distal ramp	2	
	G	Wasit Block	Neotethys	shallow subtidal (seamount)	1	
	G	Wordie Creek Formation	Boreal	outer shelf	1	
	(B) from the literature	O	Calcaires en Petits Bancs, Khaneh Kat Fm.	Neotethys	shallow subtidal	3
		O	Member 3, Kokarkuyu Formation	Neotethys	shallow subtidal	2
		Sp	Bogdo Formation	eastern Paleotethys	shallow subtidal	1
Sp		Csopak Marl Formation	western Paleotethys	inner shelf	1	
N		Calcaires Colorés, Elikah Formation	Neotethys	shallow subtidal	3	
N		Member 2, Kokarkuyu Formation	Neotethys	shallow subtidal	3	
I		Sorkh Formation	Neotethys	shallow subtidal	1	
D		Arács Marl Formation	western Paleotethys	inner shelf	3	
G		Alcsútdoboz Limestone Formation	western Paleotethys	shallow subtidal	3	
G		Feixianguan Formation	eastern Paleotethys	shallow subtidal	2	
G		Great Bank of Guizhou, Pingguo Platform	eastern Paleotethys	shallow subtidal	3	

facies, and disaster forms during the aftermath of the end-Permian mass extinction reveals the nature of these prolonged perturbations.

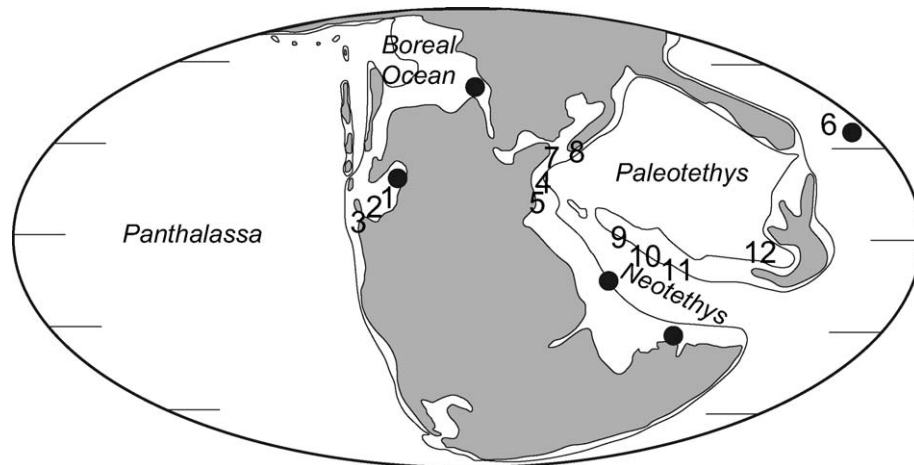


Fig. 3. Global distribution of microgastropod biofacies during the Early Triassic based on data from field and literature study (map modified from [33]). Numbers on the map indicate the approximate locations where microgastropod-dominated shell beds were deposited during the Early Triassic (members and formations scored as 2 and 3). Regions numbered 1–6 were analyzed in the field and regions numbered 7–12 were analyzed from the primary literature. (1) Western United States, upper limestone member, Thaynes Formation; (2) western United States, Sinbad Limestone Member and Virgin Limestone Member, Moenkopi Formation; (3) western United States, lower member, Union Wash Formation; (4) northern Italy, Mazzin Member, Siusi Member, Gastropod Oolite Member, Cencenighe Member, Val Badia Member, Werfen Formation; (5) northern Italy, Gastropod Oolite Member, Campil Member, Val Badia Member, Servino Formation; (6) southern Japan, basal member, Kamura Formation; (7) Hungary, Alcsútdoboz Limestone Formation [9]; (8) Hungary, Arács Marl Formation [9]; (9) Turkey, Members 2 and 3, Kokarkuyu Formation [1]; (10) Iran, ‘Calcaires colorés’, Elikah Formation [35,43]; (11) Iran, ‘Calcaires en petits bancs’, Khaneh Kat Formation [44]; (12) China, Griesbachian Feixianguan Formation [18]; Griesbachian Great Bank of Guizhou, Pingguo Platform [23]. In some formations examined in the field and in cores, microgastropods were present but not as the microgastropod facies (received a score of 1); these formations are indicated on the map with black circles: Dinwoody Formation (western USA, eastern Panthalassa), Hiraiso Formation (Japan, western Panthalassa), Wordie Creek Formation (Greenland, Boreal Ocean), Wasit Block and the Al Jil Formation (Oman, Neotethys), Taho Formation (southern Japan, Panthalassa), and Kockatea Shale (western Australia, Neotethys).

Fig. 3. Distribution globale des biofaciès à microgastéropodes au début du Trias, d’après des observations de terrain et des données de la littérature (carte modifiée d’après [33]). Les chiffres de la carte indiquent les localisations approximatives des bancs coquilliers contenant essentiellement des microgastéropodes, déposés au début du Trias (membres et formations répertoriés « 2 » et « 3 »). Les régions numérotées de 1 à 6 ont été étudiées sur le terrain et les régions numérotées de 7 à 12 ont été étudiées d’après les publications originales. (1) Ouest des États-Unis, *Upper Limestone Member*, formation de Thaynes ; (2) Ouest des États-Unis, *Sinbad Limestone Member* et *Virgin Limestone Member*, formation de Moenkopi ; (3) Ouest des États-Unis, membre inférieur, formation de Union Wash ; (4) Nord de l’Italie, membre de Mazzin, membre de Siusi, *Gastropod Oolite Member*, membre de Cencenighe, membre de Val Badia, formation de Werfen ; (5) Nord de l’Italie, *Gastropod Oolite Member*, Campil Member, Val Badia Member, formation de Servino ; (6) Sud du Japon, membre basal, formation de Kamura ; (7) Hongrie, *Alcsútdoboz Limestone Formation* (9) ; (8) Hongrie, formation de Aracs Marl (9) ; (9) Turquie, membres 2 et 3, formation Kokarkuyu (1) ; (10) Iran, Calcaires colorés, formation d’Elikah [35,43] ; (11) Iran, Calcaires en petits bancs, formation de Khaneh Kat [44] ; (12) Chine, *Griesbachian Feixianguan Formation* [18] ; *Griesbachian Great Bank* de Guizhou, plate-forme de Pingguo [23]. Dans certaines formations étudiées sur le terrain et à partir de carottes, des microgastéropodes étaient présents, mais pas associés au faciès à microgastéropodes (repérés par le chiffre 1) ; ces formations sont repérées sur la carte par des cercles noirs : formation de Dinwoody (Ouest des USA, Panthalassa orientale), formation de Hiraiso (Japon, Panthalassa occidentale), formation de Wordie Creek (Groenland, océan Boréal), Wasit Block et formation de Al Jil (Oman, Néotéthys), formation de Taho (Sud du Japon, Panthalassa) et Kockatea Shale (Ouest de l’Australie, Néotéthys).

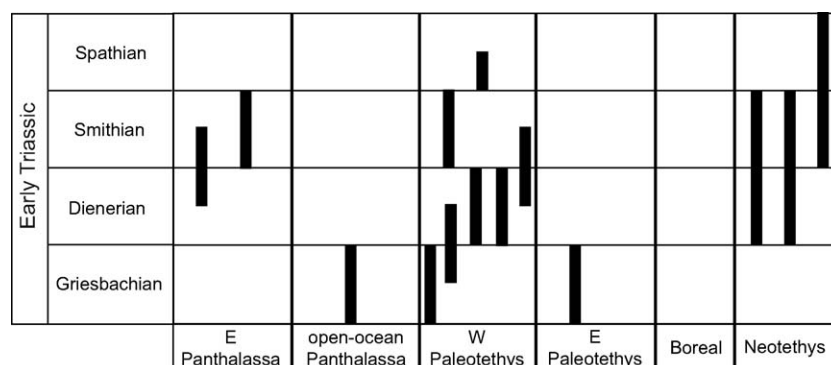


Fig. 4. Figure displaying only Lower Triassic Members and Formations around the world scored as 3 using field- and literature-based data. Eastern Panthalassa: Sinbad Limestone Member, Moenkopi Formation; lower member, Union Wash Formation. Open-ocean Panthalassa: basal member, Kamura Formation. Western Paleotethys: Alcsútdoboz Limestone Formation; Arács Marl Formation; Siusi Member, Gastropod Oolite Member, Werfen Formation; Gastropod Oolite Member, Campil Member, Val Badia Member (lower Spathian), Servino Formation. Eastern Paleotethys: Great Bank of Guizhou, Pingguo Platform. Neotethys: Member 2, Kokarkuyu Formation; Calcaires Colorés, Elikah Formation; 'Calcaires en petits bancs', Khaneh Kat Formation.

Fig. 4. Répartition géographique des membres et des formations du Trias inférieur, répertoriés « 3 », à partir des données de terrain et de la littérature. Panthalassa orientale : *Sinbad Limestone Member*, formation de Moenkopi ; *lower member*, formation de Union Wash. Panthalassa, océan ouvert : membre basal, formation de Kamura. Paléotéthys occidentale : *Alcsútdoboz Limestone Formation* ; formation de Aracs Marl ; membre de Siusi, *Gastropod Oolite Member*, formation de Werfen ; *Gastropod Oolite Member*, Campil Member, Val Badia Member (Spathien inférieur), formation de Servino. Paléotéthys orientale : *Great Bank* de Guizhou, plate-forme de Pingguo. Néotéthys : membre 2, formation de Kokarkuyu ; Calcaires colorés, formation de Elikah ; Calcaires en petits bancs, formation de Khaneh Kat.

Table 3

Number and percentage of microgastropod-dominated shell beds in examples of stratigraphic units scored as '3' in the field. **I**: Induan; **N**: Nammalian; **Sm**: Smithian

Tableau 3 : Abondance et pourcentage des bancs coquilliers essentiellement édifiés par des microgastéropodes dans des niveaux stratigraphiques répertoriés « 3 » sur le terrain. **I** : Indusien ; **N** : Nammalien ; **Sm** : Smithien.

		total # shell beds	# microgastropod-dominated shell beds	% microgastropod-dominated shell beds
Sm	Campil Member	48	12	25%
N	Sinbad Limestone Member	82	17	21%
N	Gastropod Oolite Member	57	27	47%
I	Siusi Member	77	14	18%

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