



Bulgarian National Science Program  
“Environmental Protection and Reduction  
of Risks of Adverse Events and Natural Disasters”



# Palaeoenvironmental changes in the Moesian Basin (Bulgaria) during the Toarcian

Lubomir Metodiev, Elena Koleva-Rekalova, Milena Georgieva, Tanya Stoylkova



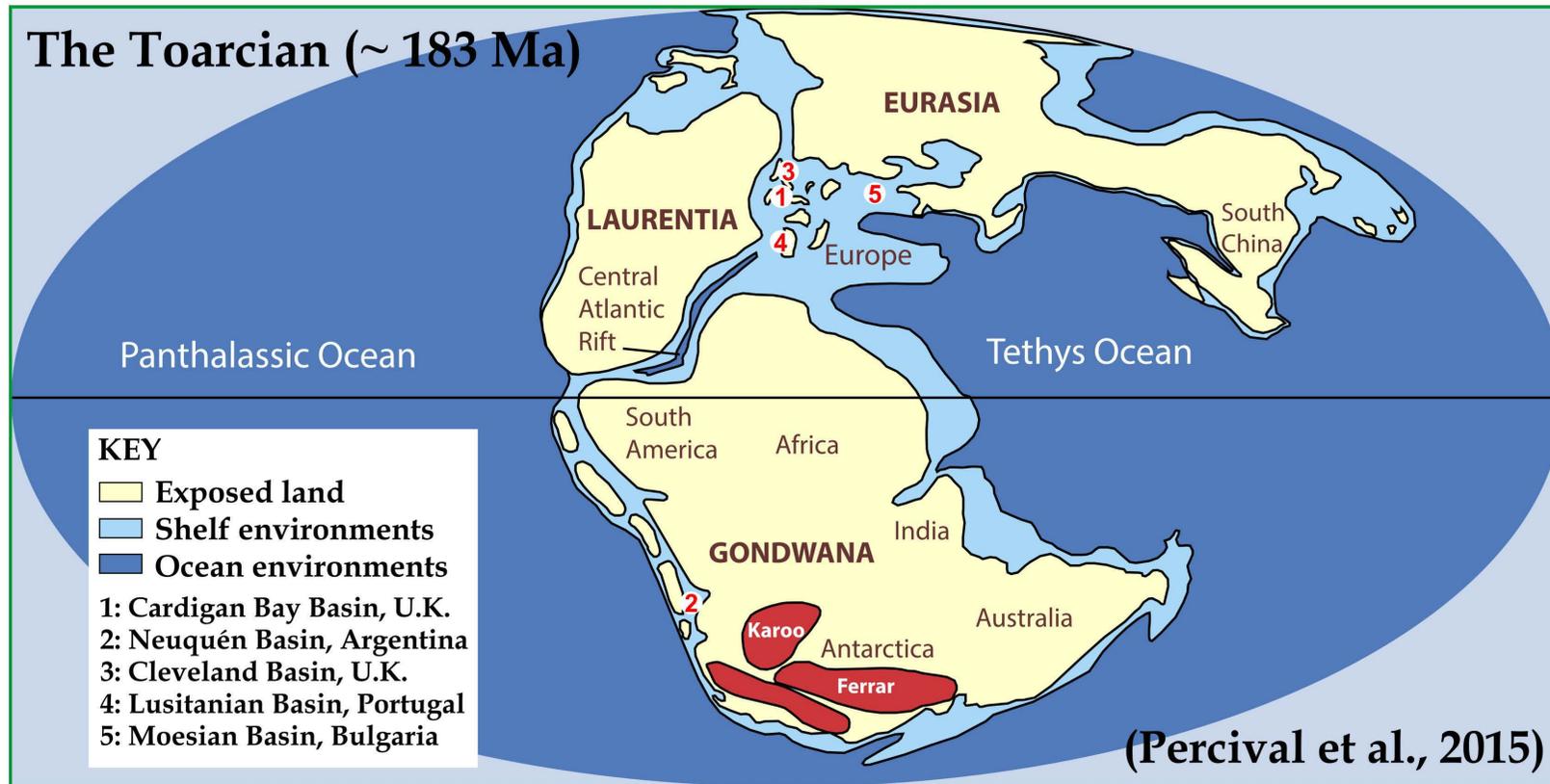
Geological Institute, Bulgarian Academy of Sciences  
Sofia University “St. Kliment Ohridski”



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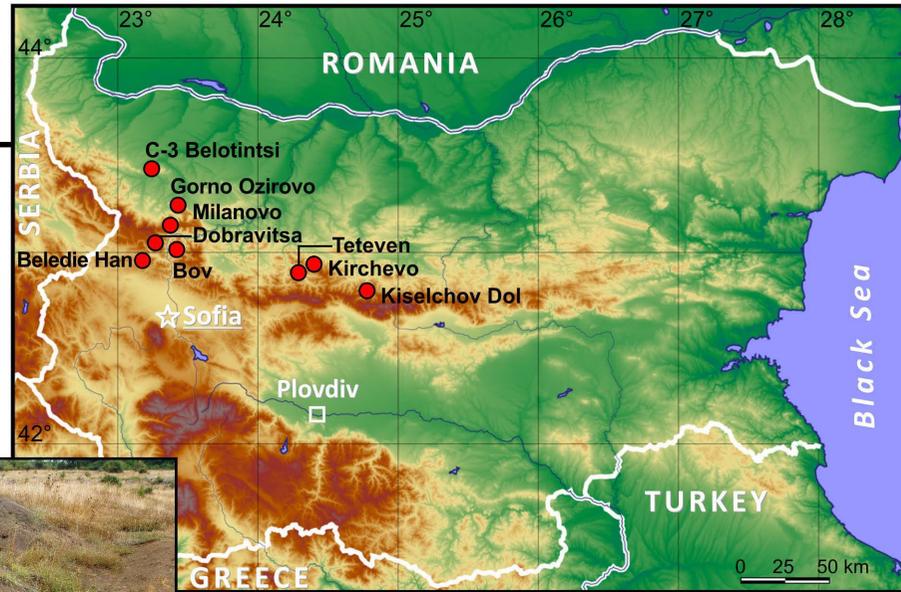
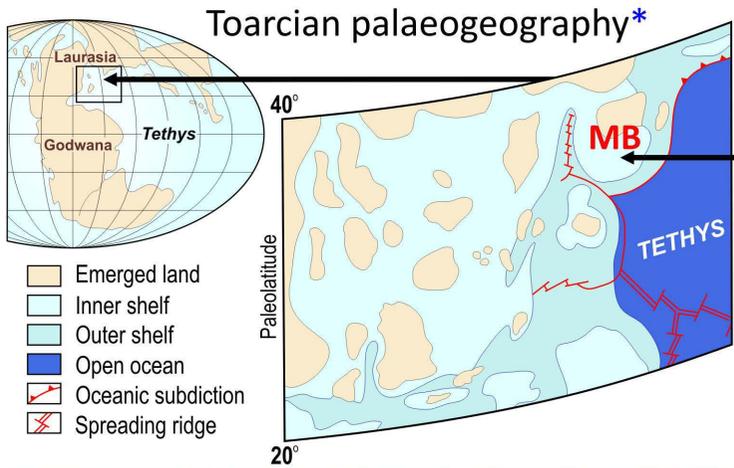


There is a wide range of data behind the concept that the late Pliensbachian–early Toarcian span (184.5–181.5 Ma) was a time of Earth-scale palaeoenvironmental changes, *e.g.*, rapid global warming, sea-level rise, perturbations in the carbon cycle and the development of widespread anoxia, known as **the early Toarcian Oceanic Anoxic Event (T-OAE)**. The T-OAE is **deemed amongst the major biogeochemical disturbances in the Mesozoic**. A biotic crisis in the marine realm, known as the **early Toarcian mass extinction (T-ME)**, was broadly recognized. Many studies linked the T-OAE and the T-ME with **the eruption of the Karoo–Ferrar igneous province** in the southern hemisphere and this link continues to collect evidence from numerous sites from around the world\*.

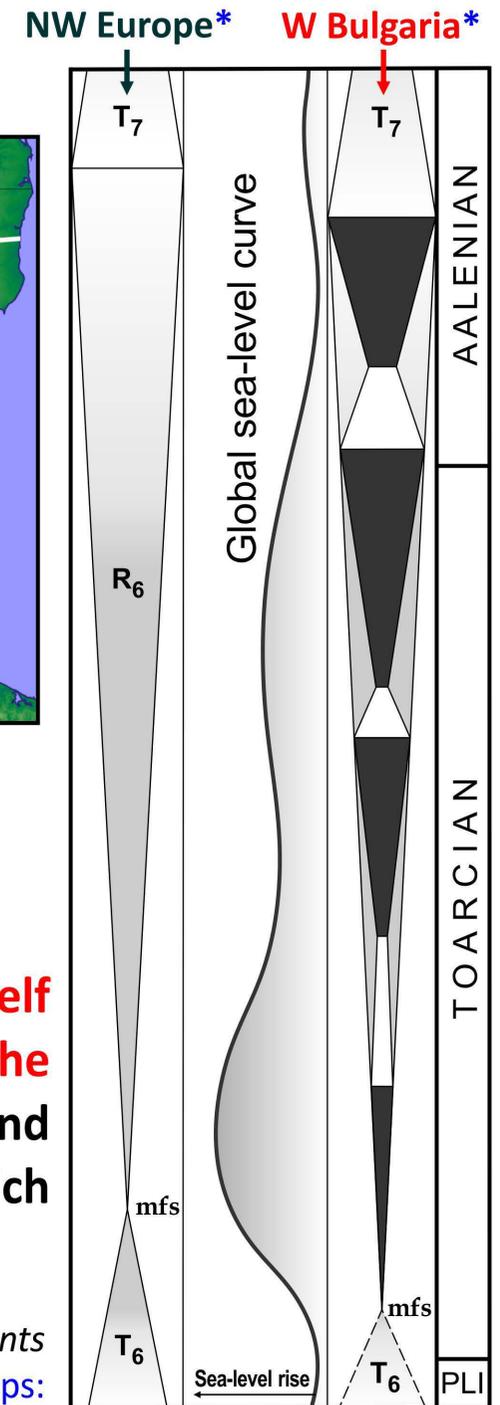


\*Based upon: Wignall (2001), <https://doi.org/10.2113/gselements.1.5.293>; Jenkyns (2010), <https://doi.org/10.1029/2009GC002788>; Percival *et al.* (2015), <http://dx.doi.org/10.1016/j.epsl.2015.06.064>; Korte *et al.* (2015), <https://doi.org/10.1038/ncomms10015>.

# The T-OAE in Bulgaria (depositional framework)



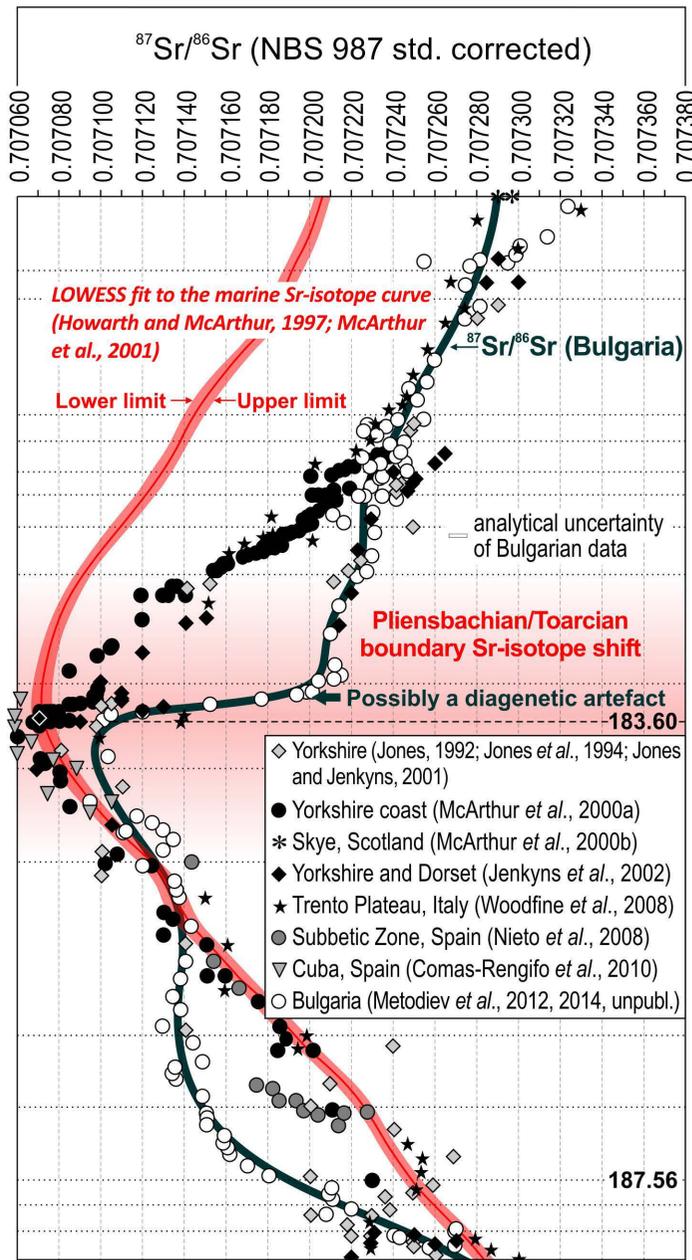
Bulgarian Toarcian sections (up) and strata (left): a) shallow-water; b) deeper-water sediments



The T-OAE and T-ME have been indicated in sections representing **inner-shelf deposits of the Moesian Basin (MB)**, which was **developed proximal to the southern Eurasian passive continental margin**. The overall depositional trend fits into the regressive phase of the **second-order Ligurian (R6) T-R cycle**, which is widely recognizable in the Jurassic basins of NW Europe.

\*After Bassoulet *et al.* (1992), *Atlas Tethys Paleoenvironmental Maps*; Vail *et al.* (1991), *Cycles and events in stratigraphy*; De Graciansky *et al.* (1998), <https://doi.org/10.2110/pec.98.02.0467>; Hallam (2001), [https://doi.org/10.1016/S0031-0182\(00\)00229-7](https://doi.org/10.1016/S0031-0182(00)00229-7); Koleva-Rekalova *et al.* (2007), *Geologica Balc.*

# The T-OAE in Bulgaria ( $^{87}\text{Sr}/^{86}\text{Sr}$ data)

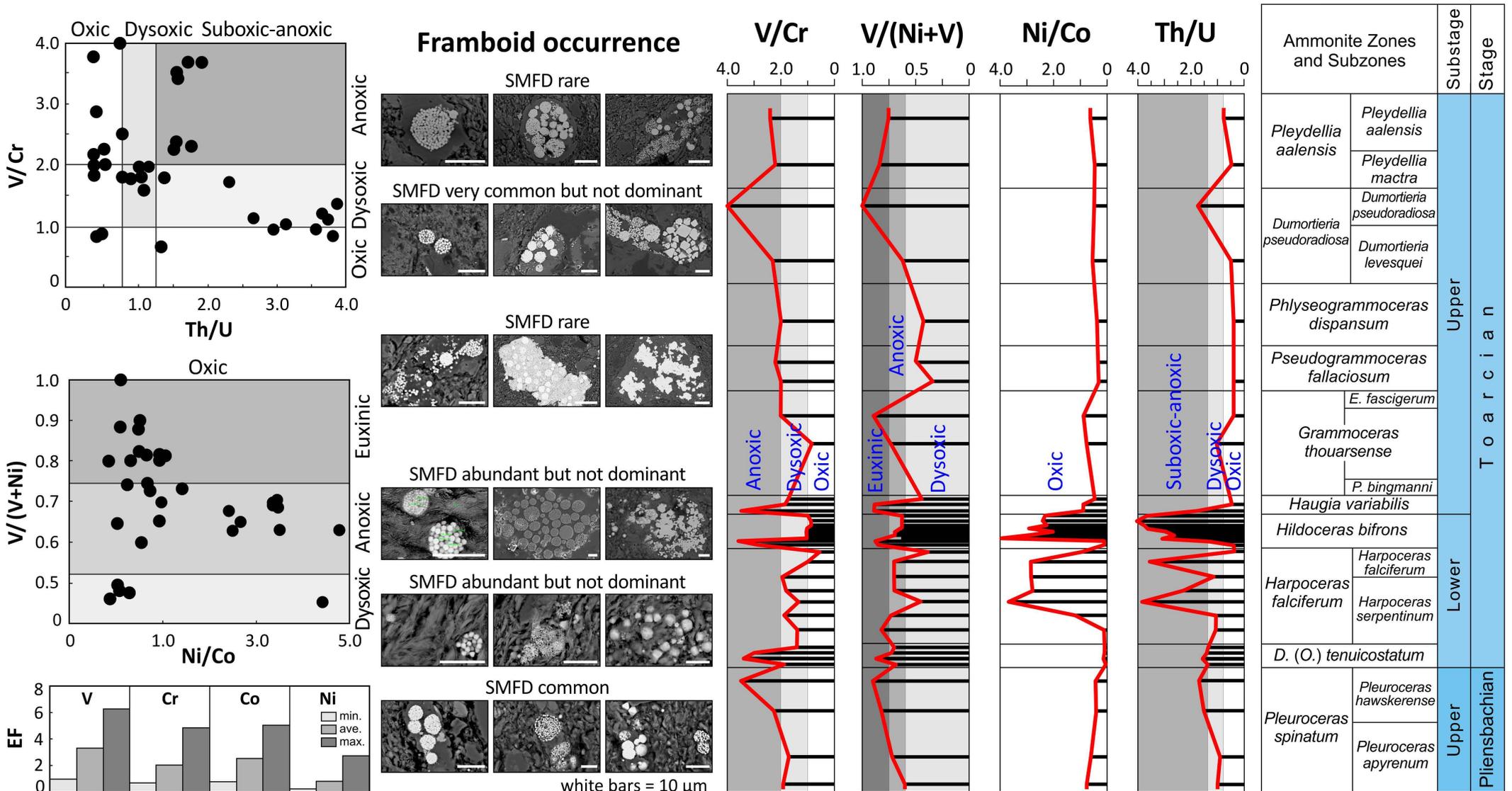


Numerical age (Ma)	Ammonite Zones and Subzones	Substage	Stage	Series
180.0	<i>Pseudogrammoceras fallaciosum</i>	Upper	Toar	ar
	<i>E. fascigerum</i>			
	<i>Grammoceras thouarsense</i>			
181.0	<i>P. bingmanni</i>	Lower		
	<i>Haugia variabilis</i>			
	<i>Hildoceras bifrons</i>			
182.0	<i>Harpoceras falciferum</i>	Lower	Toar	ar
	<i>Harpoceras serpentinum</i>			
183.0	<i>D. (O.) tenuicostatum</i>	Upper		
184.0	<i>Pleuroceras spinatum</i>			
	<i>Pleuroceras hawskerense</i> <i>Pleuroceras apyrenum</i>			
185.0	<i>Amaltheus margaritatus</i>	Upper		
	<i>Amaltheus gibbosus</i>			
186.0	<i>Amaltheus subnodosus</i>	Lower		
187.0	<i>Amaltheus stokesi</i>			
188.0	<i>Oistoceras figulinum</i> <i>Aegoceras capricornus</i> <i>Aegoceras maculatum</i>			

A decrease in  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios through the upper Pliensbachian, reaching a minimum around the P/T boundary, and followed by gradual increase throughout the Toarcian was recorded.

Biostratigraphy and data framework: ammonite zones are after Metodiev (2008); (sub)stage boundaries are taken from Pálffy and Smith (2000), [https://doi.org/10.1130/0091-7613\(2000\)028<0747:SBEJEO>2.3.CO;2](https://doi.org/10.1130/0091-7613(2000)028<0747:SBEJEO>2.3.CO;2) and McArthur et al. (2002a), *Earth Plan. Sci. Lett.*; for Sr-isotope data, see the papers cited in the insets close to the Sr-curve.

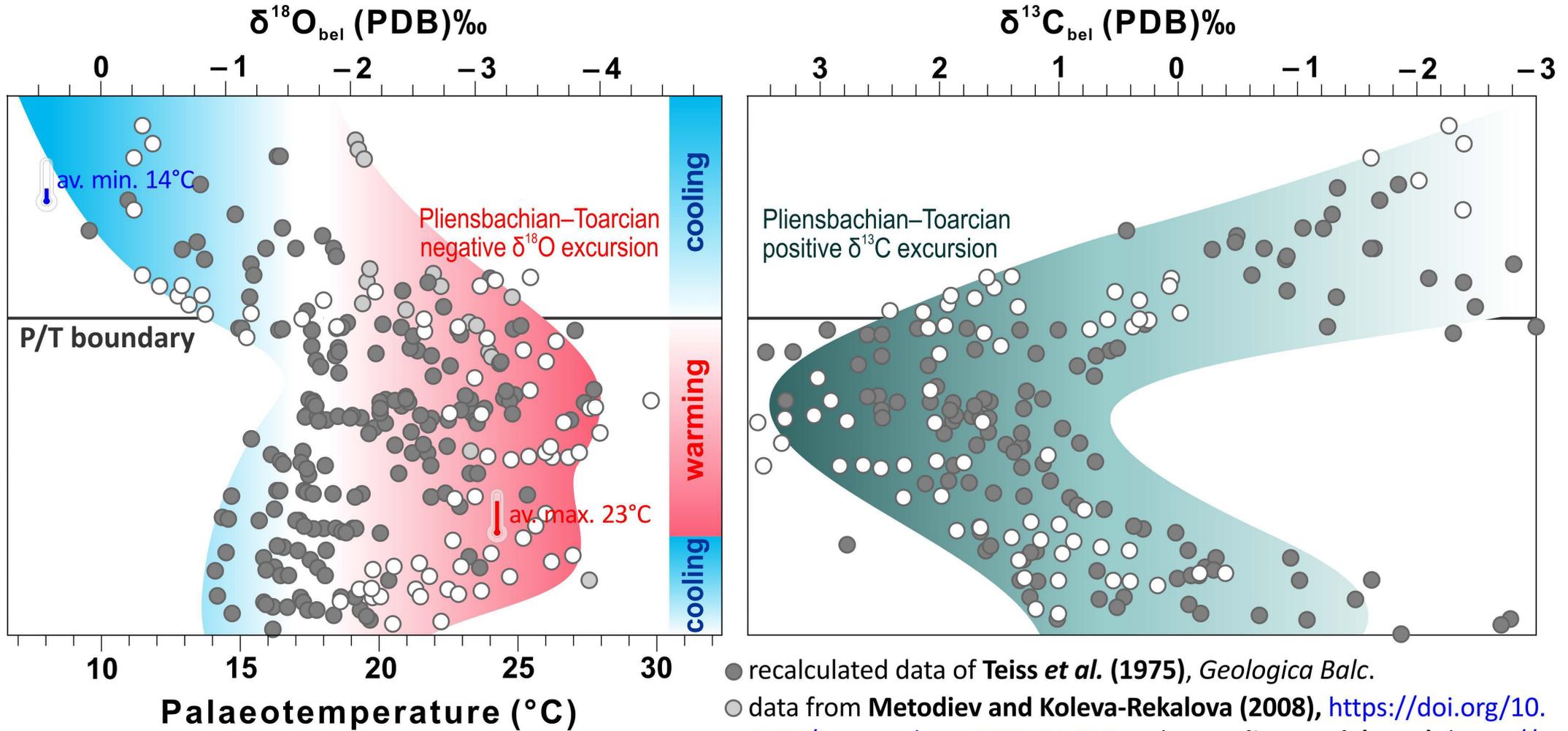
# The T-OAE in Bulgaria (elemental data and framboid distribution)\*



Oxygen deficiency was evidenced in narrow redox intervals with elevated V/Cr, V/(Ni+V) and Th/U ratios, and smallest mean framboid diameters (SMFD).

\*Modified from Metodiev *et al.* (2020, 2021), *Rev. Bulg. Geol. Soc.*, <https://doi.org/10.52215/rev.bgs.2021.82.3.115>.

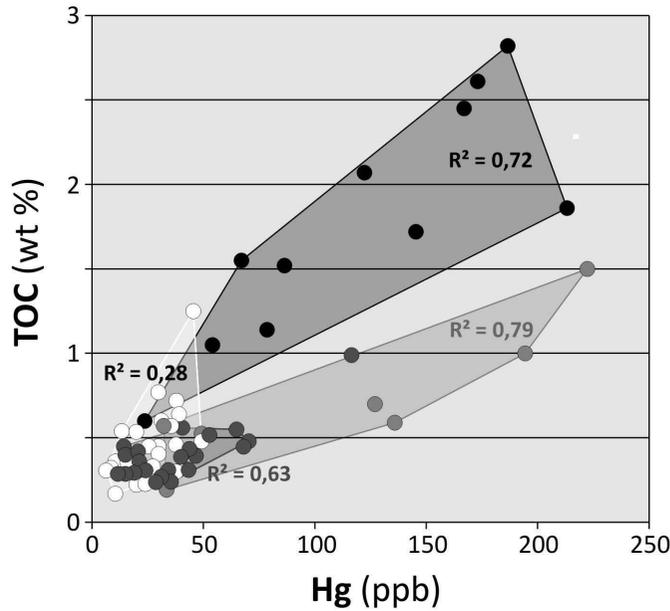
## The T-OAE in Bulgaria ( $\delta^{13}\text{C}_{\text{bel}}$ and $\delta^{18}\text{O}_{\text{bel}}$ profiles)



- recalculated data of Teiss *et al.* (1975), *Geologica Balc.*
- data from Metodiev and Koleva-Rekalova (2008), <https://doi.org/10.1016/j.apgeochem.2008.04.010> and Metodiev *et al.* (2014), <https://doi.org/10.1016/j.palaeo.2014.04.025>
- Pugh *et al.* (2019), <https://doi.org/10.7287/peerj.preprints.27948v1>

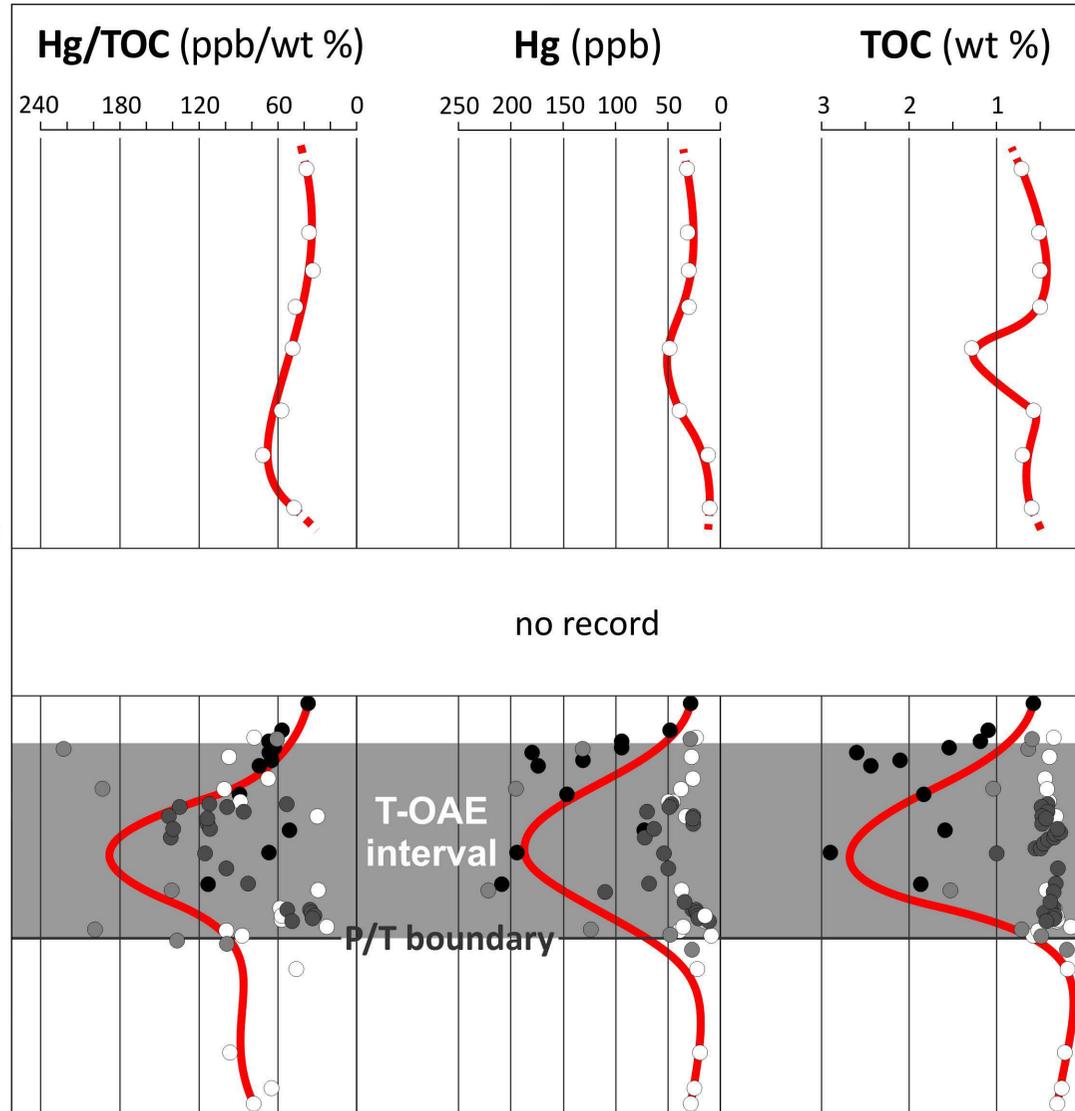
The  $\delta^{13}\text{C}_{\text{bel}}$  and  $\delta^{18}\text{O}_{\text{bel}}$  profiles showed trends having a **decline in oxygen-isotope** signatures and **rising in carbon-isotope** values, both of  $>3\text{‰}$ , around the P/T boundary.

# The T-OAE in Bulgaria (TOC, Hg and Hg/TOC data)



○●● Metodiev *et al.* (2019), *Rev. Bulg. Geol. Soc.*

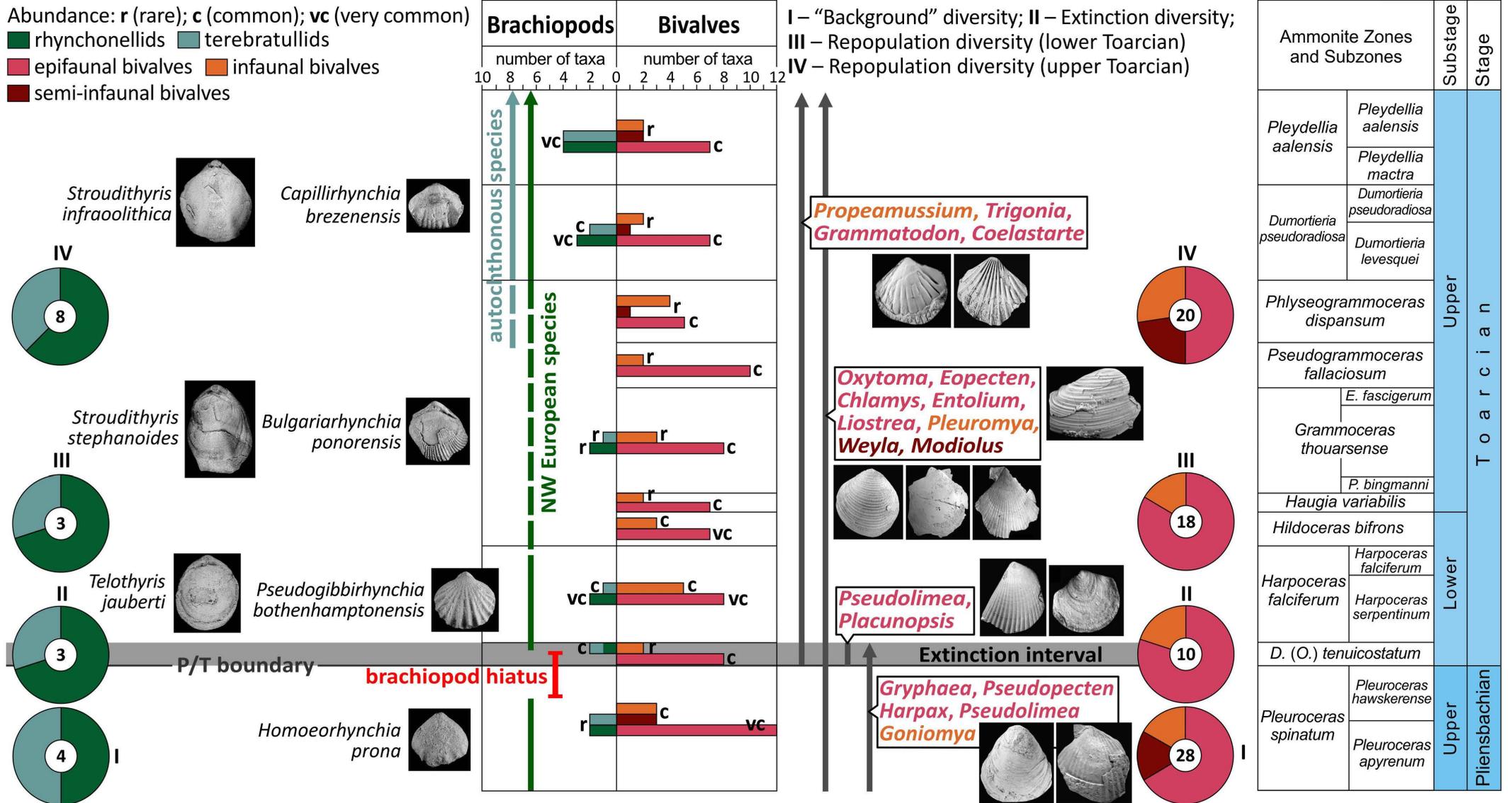
● Pugh *et al.* (2019), <https://doi.org/10.7287/peerj.preprints.27948v1>



Ammonite Zones and Subzones		Substage	Stage
<i>Pleydellia aalensis</i>	<i>Pleydellia aalensis</i>	Upper T o a r c i a n	
	<i>Pleydellia mactra</i>		
<i>Dumortiera pseudoradiosa</i>	<i>Dumortiera pseudoradiosa</i>		
	<i>Dumortiera levesquei</i>		
<i>Phlyseogrammoceras dispansum</i>			
<i>Pseudogrammoceras fallaciosum</i>			
<i>E. fascigerum</i>			
<i>Grammoceras thouarsense</i>			
<i>P. bingmanni</i>			
<i>Haugia variabilis</i>			
<i>Hildoceras bifrons</i>			
<i>Harpoceras falciferum</i>	<i>Harpoceras falciferum</i>	Lower	
	<i>Harpoceras serpentinum</i>		
<i>D. (O.) tenuicostatum</i>			
<i>Pleuroceras spinatum</i>	<i>Pleuroceras hawskerense</i>	Upper	Pliensbachian
	<i>Pleuroceras apyrenum</i>		

Enrichments in mercury (Hg), recorded as shifts in TOC, Hg and Hg/TOC ratios concomitant with the  $\delta^{13}\text{C}_{\text{bel}}$  and  $\delta^{18}\text{O}_{\text{bel}}$  excursions, were attributed to the eruption of the Karoo-Ferrar.

# The T-ME in Bulgaria (bivalve and brachiopod record)



**A ~40% loss of bivalve species and brachiopod hiatus around the P/T boundary, and later brachiopod occurrences, with autochthonous taxa, were recorded and considered to be part of the T-ME.**

Bivalve and brachiopod records from: Pugh (2018), *Uni Leeds PhD thesis* (unpubl.); Pugh et al. (2019), <https://doi.org/10.7287/peerj.preprints.27948v1>; Tchoumatchenco (1972), [https://doi.org/10.1016/0031-0182\(72\)90020-X](https://doi.org/10.1016/0031-0182(72)90020-X) and Motchurova-Dekova et al. (in prep.). 8

## Conclusions

1. As inferred from the Bulgarian stratigraphic sections, the **overall deposition around the T-OAE time and thereafter** is related with **widespread condensations** and a **regional collapse of the carbonate platform productivity**.
2. The  $^{87}\text{Sr}/^{86}\text{Sr}$  data revealed an **increased freshwater influx** within the **late Pliensbachian–early Toarcian** time span.
3. Oxygen deficiency was indicated in several sections but **anoxic settings were not widely recorded**.
4. The  $\delta^{13}\text{C}_{\text{bel}}$  and  $\delta^{18}\text{O}_{\text{bel}}$  data denote **a rapid seawater warming during the early Toarcian**.
5. Significant **loss of bivalves** and **brachiopods** was evidenced **around the P/T boundary**.
6. The **T-OAE–T-ME link remains unclear**. Rapid **warming** rather than **oxygen deficiency** has been **driving the T-ME in the Moesian Basin**.



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