Major extinction events in the light of stable isotope compositions

Permian-Triassic boundary events in continuous marine successions in Hungary

Based on

Haas, J., Demény, A., Hips, K., Vennemann, T.W. (2006): Carbon isotope excursions and microfacies changes in marine Permian–Triassic boundary sections in Hungary. Palaeogeography, Palaeoclimatology, Palaeoecology, 237, 160–181.

János Haas, Attila Demény, Kinga Hips, Norbert Zajzon, Tamás G. Weiszburg, Milan Sudar, József Pálfy (2006): Biotic and environmental changes in the Permian–Triassic boundary interval recorded on a western Tethyan ramp in the Bükk Mountains, Hungary. Global and Planetary Change (in press)

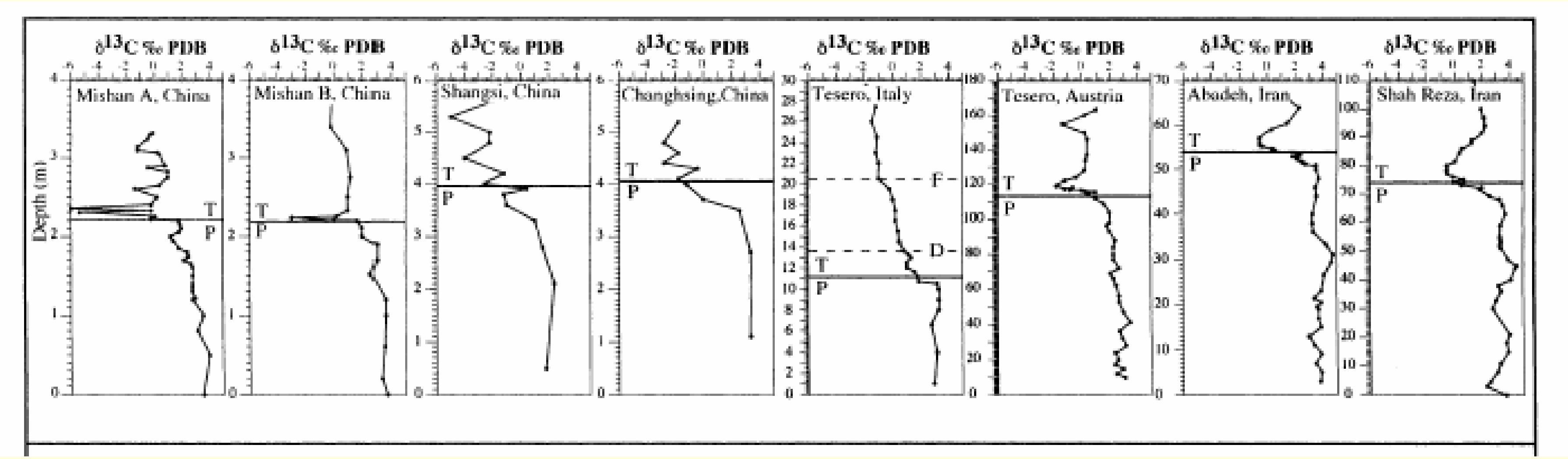
Permian-Triassic extinction

Possible causes:

- impact of extraterrestrial body
- continental flood basalt volcanism (Siberian traps)
- lethal release of gases (CO_2, CH_4)

Observation:

The mass extinction event is associated with strong negative $\delta^{13}C$ shift.



Heydari et al., 2001

Processes producing ^{12}C-enrichment in the sediments

- Productivity drop
- Rapid turnover of anoxic deep water
- Volcanism
- Cometary impact
- Release of methane hydrates

Erwin et al. (2002): $\delta^{13}C$ peak superponed on gradual change
$\Rightarrow$ productivity change and something else.

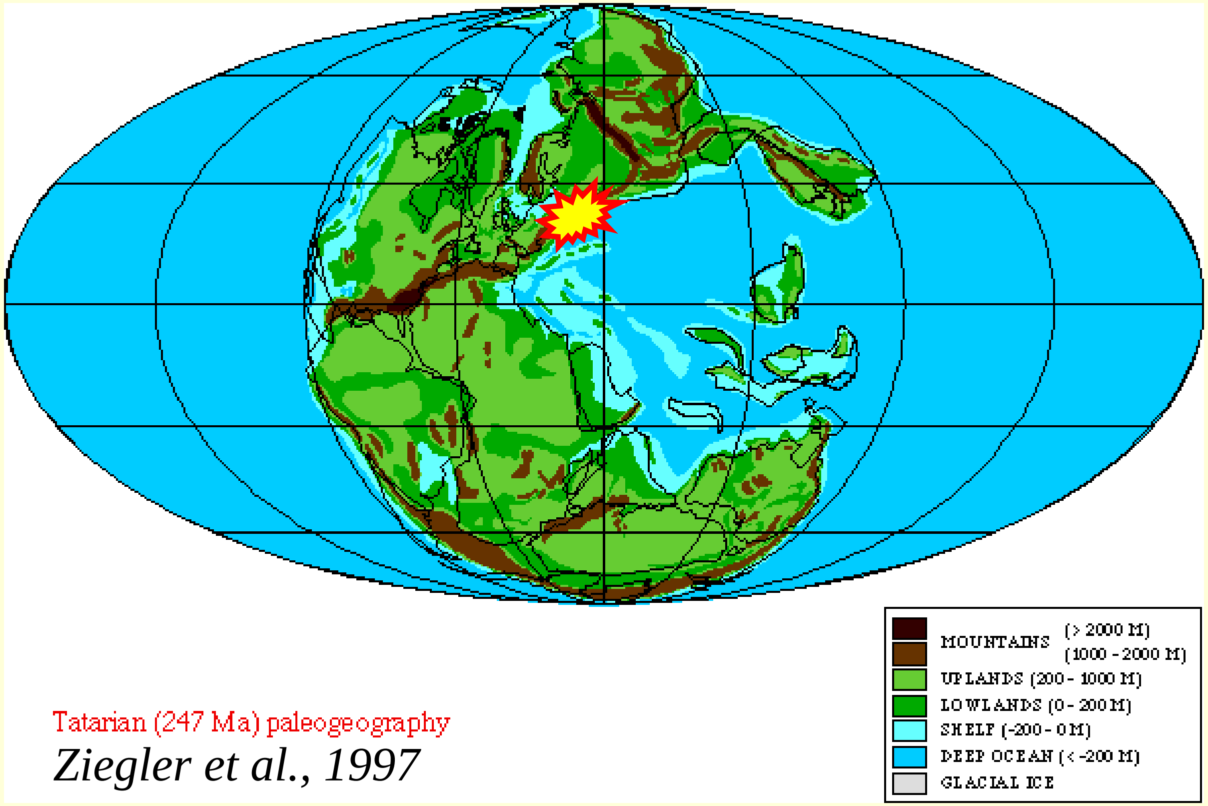
Overall $\delta^{13}C$ shift (up to -10 ‰):
Mass balance calculations including global carbon reservoirs:
Massive release of methane is the most likely cause.

Questions:

- Why is the $\delta^{13}C$ peak missing in many Alpine sections?
- What is the mechanism of methane release?

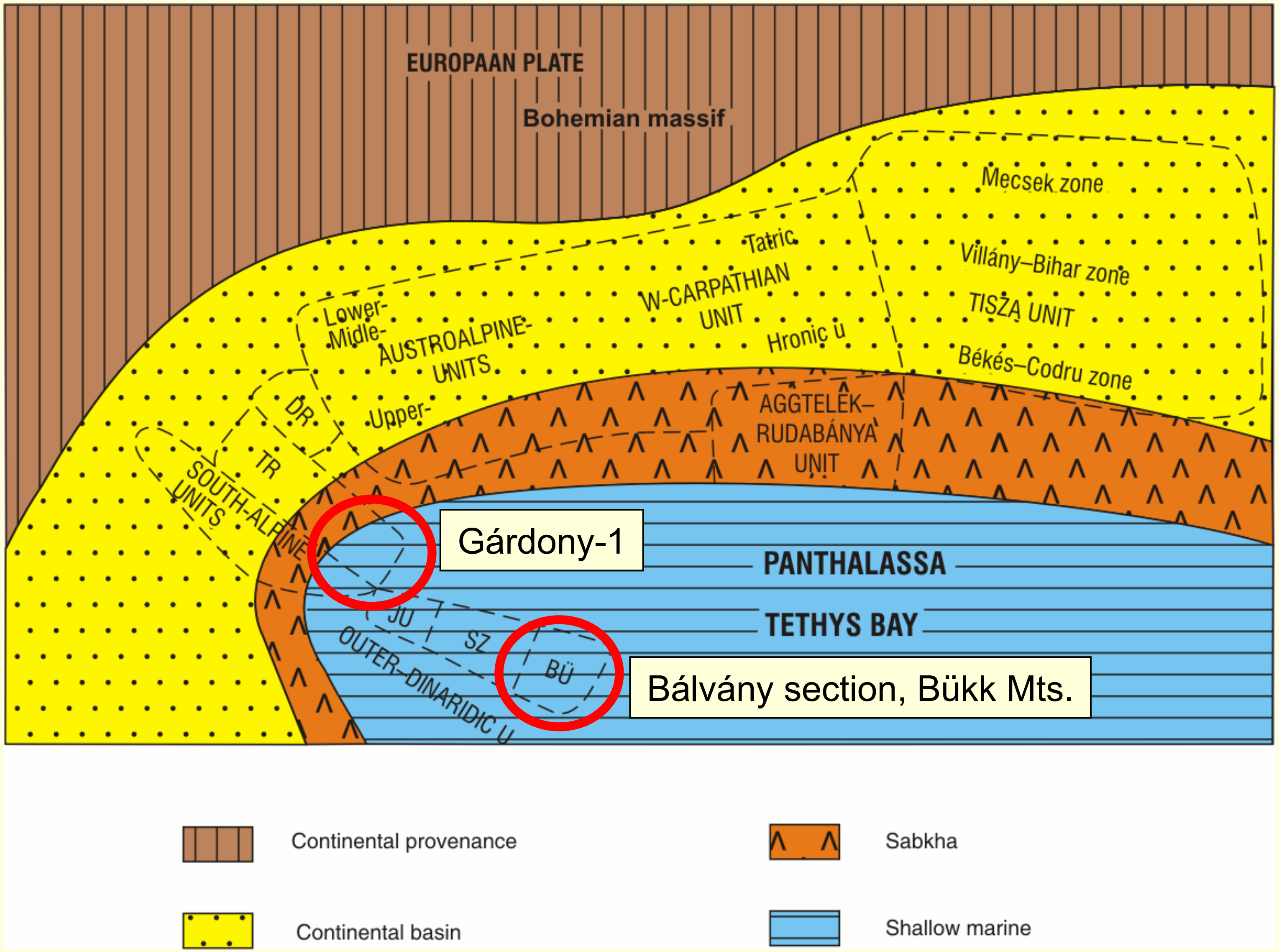
Sections studied:

- Oolitic section of the Gárdony-1 core, W. Hungary.
- Limestone - marl section of the Bükk Mts., N. Hungary

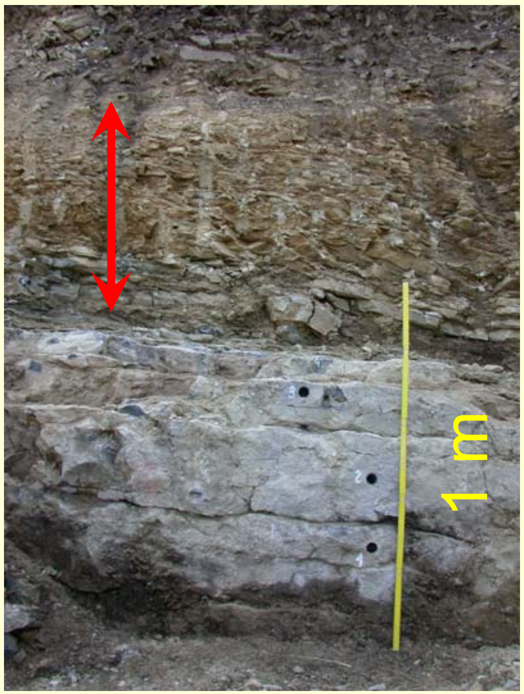


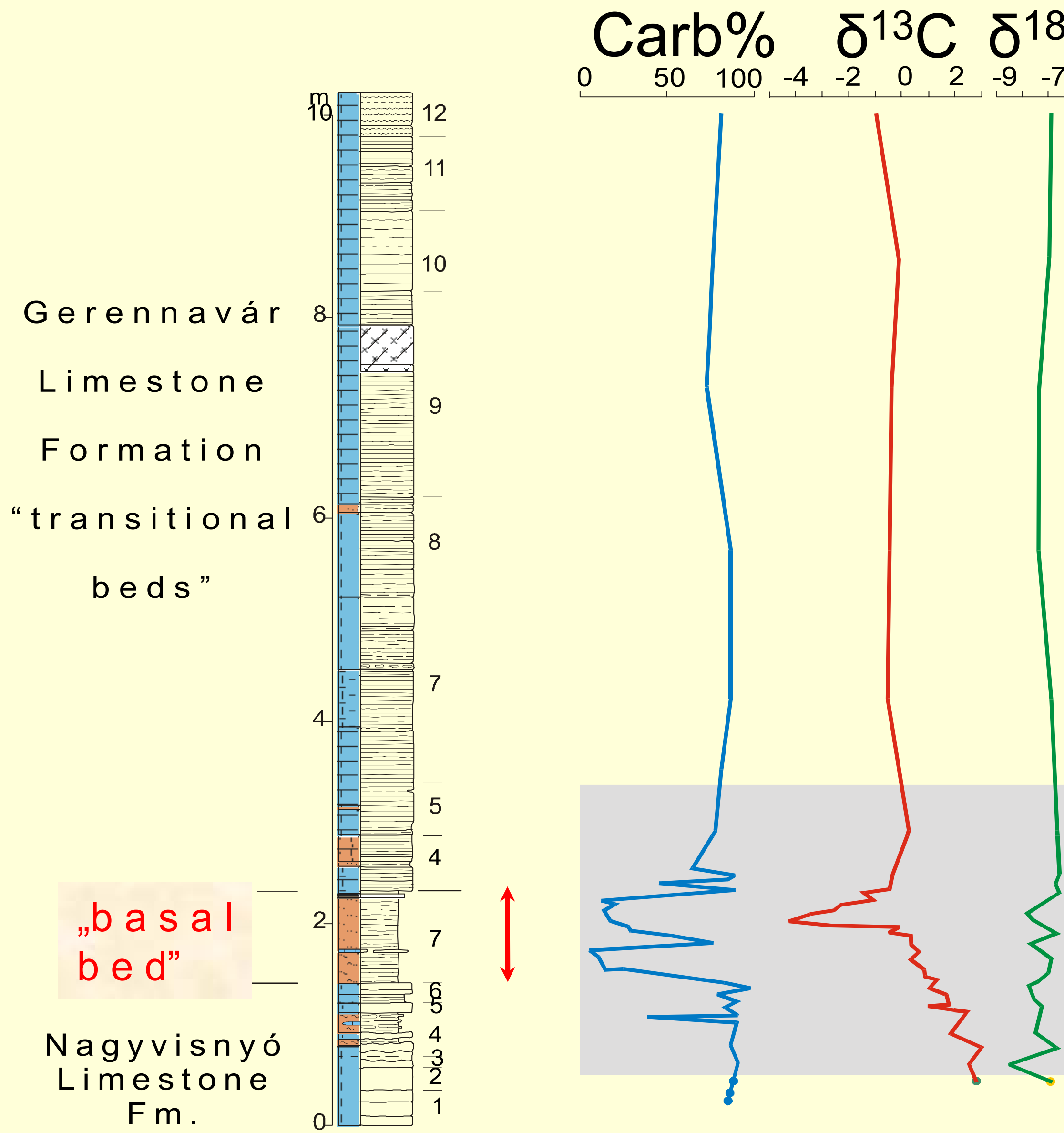
Tatarian (247 Ma) paleogeography

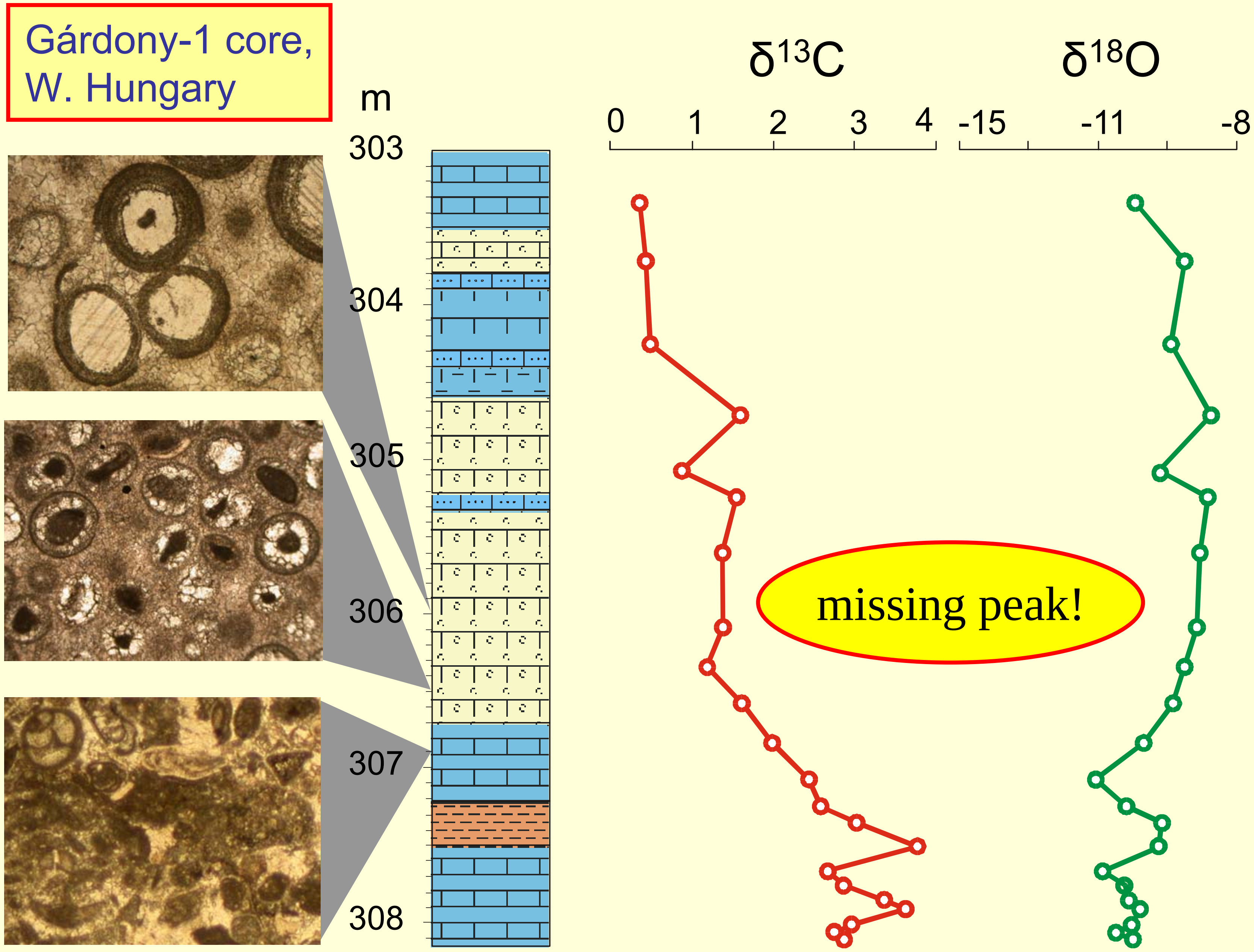
Ziegler et al., 1997


EUROPAAN PLATE
Bohemian massif
Mecsek zone
Villány–Bihar zone
TISZA UNIT
Békés–Codru zone
Tatric
W-CARPATHIAN UNIT
Hronic u
Lower-
Midle-
AUSTROALPINE-
UNITS
Upper-
DR
TR
SOUTH-ALPINE UNITS
AGGTELEK–RUDABÁNYA UNIT
Gárdony-1
PANTHALASSA
TETHYS BAY
JU
SZ
BÜ
OUTER–DINARIDIC U
Bálvány section, Bükk Mts.
Continental provenance
Sabkha
Continental basin
Shallow marine

Bálvány, Bükk Mts.,
N. Hungary





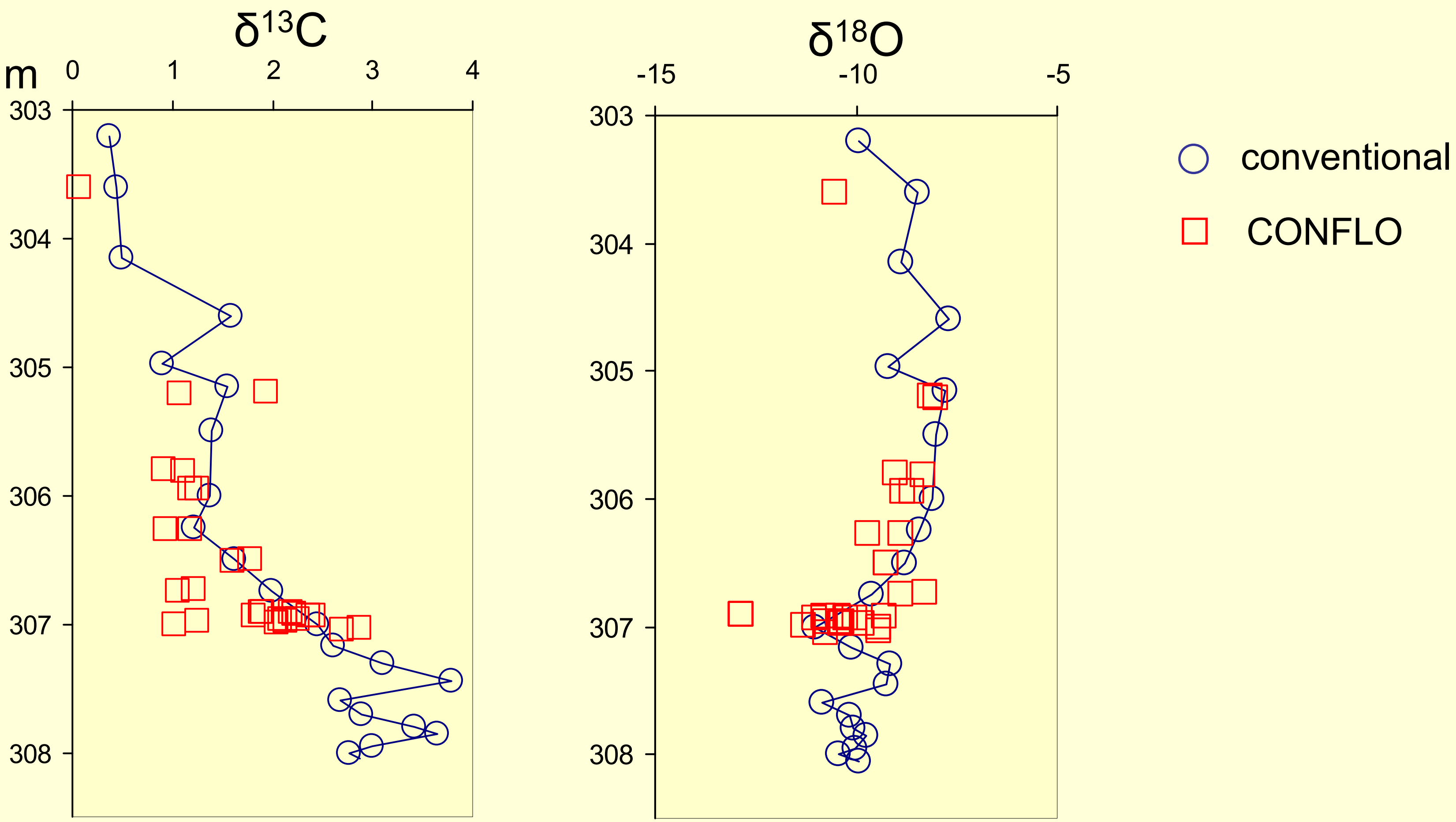


Gárdony-1 core,
W. Hungary
m
303
304
305
306
307
308
$\delta^{13}C$
0
1
2
3
4
$\delta^{18}O$
-15
-11
-8
missing peak!

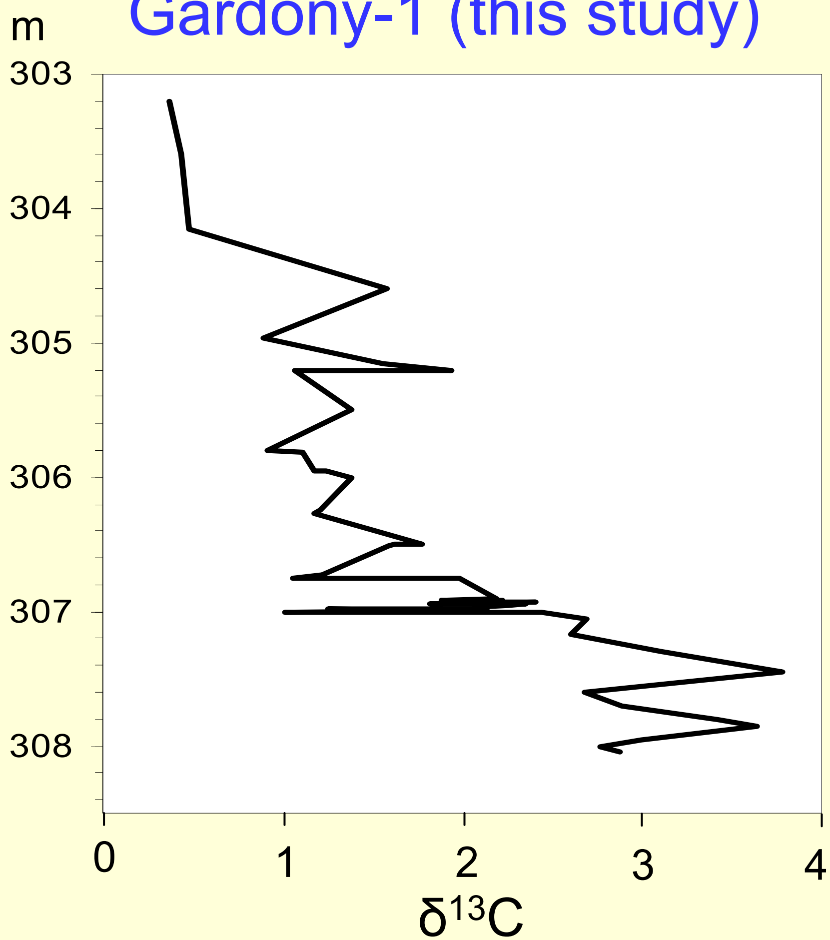
<u>Sediment reworking</u>

Frequent in oolitic shallow water sediments.

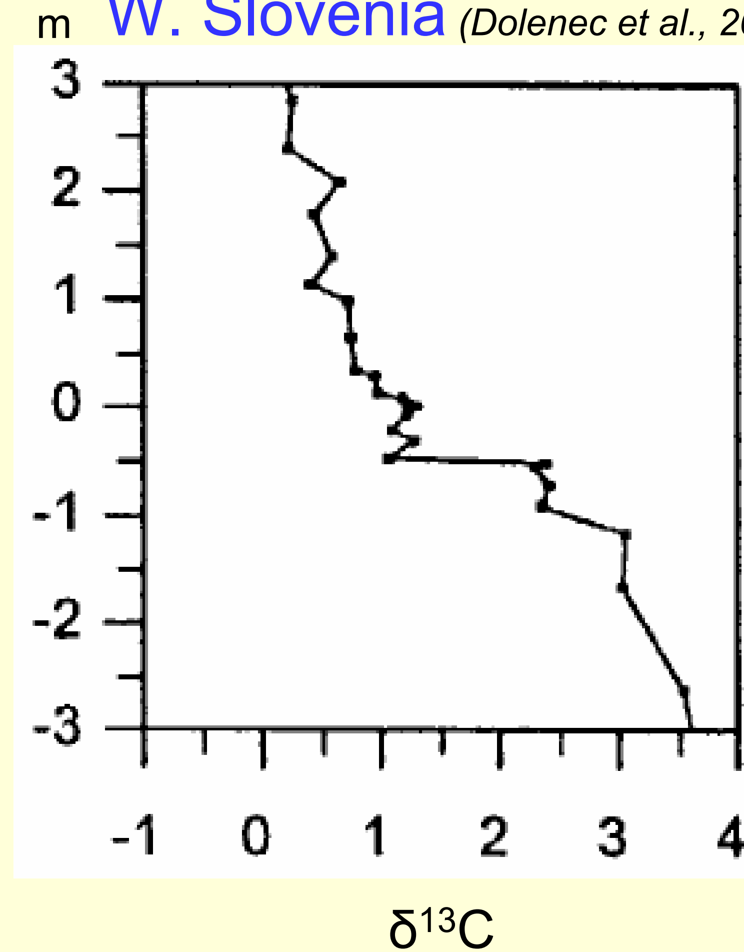
⇒ High-resolution analyses of individual ooides.



Gárdony-1 (this study)



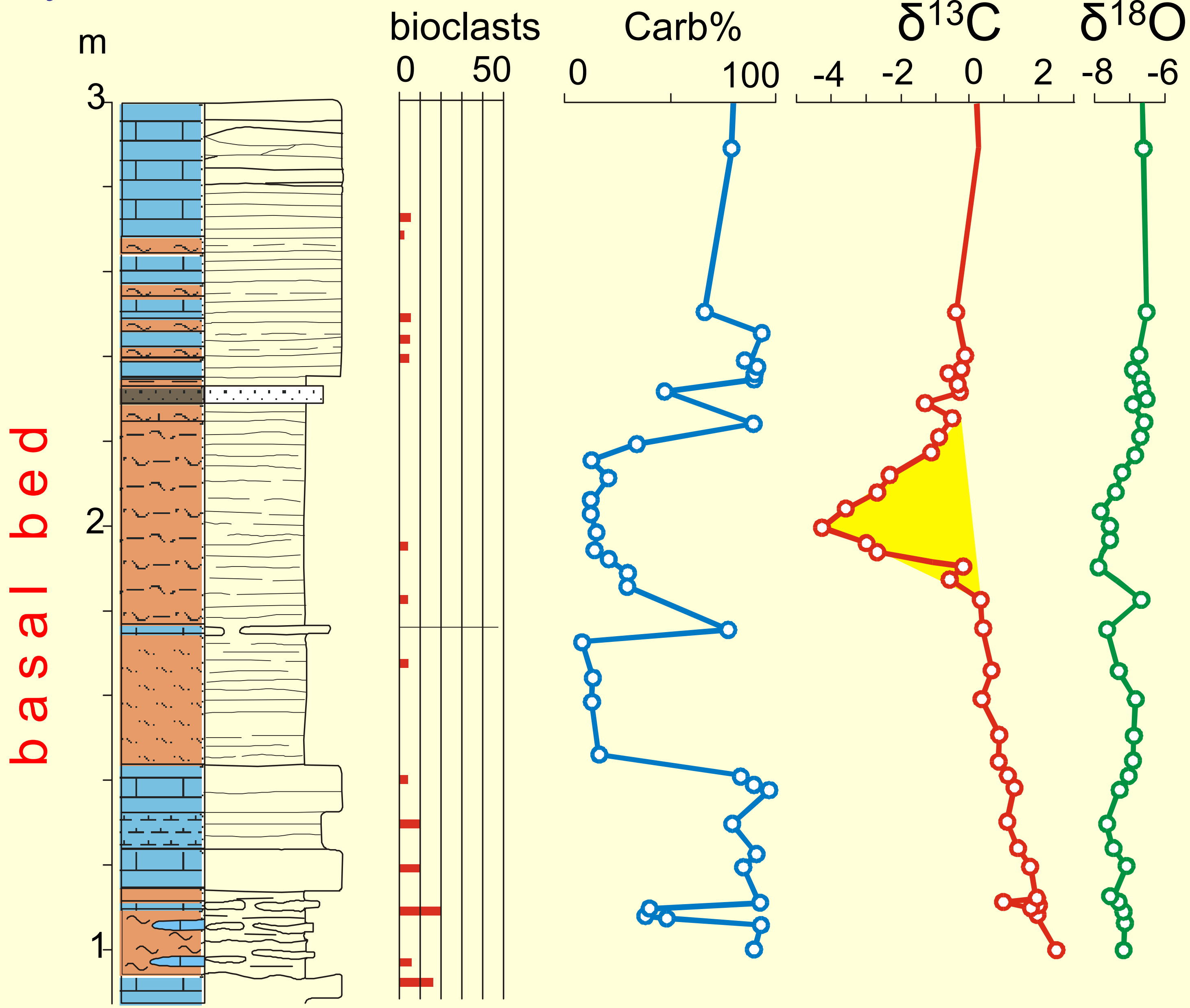
W. Slovenia *(Dolenec et al., 2001)*



The $\delta^{13}C$ peak is still missing.
Cause: combined effect of sediment reworking and diagenesis.

⇒ The Alpine sections may not preserve the original record.

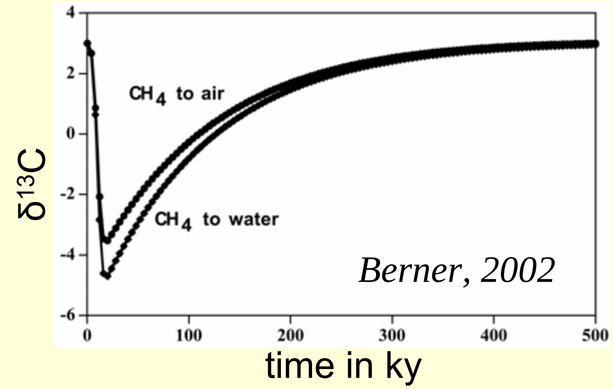
Bálvány, Bükk Mts.



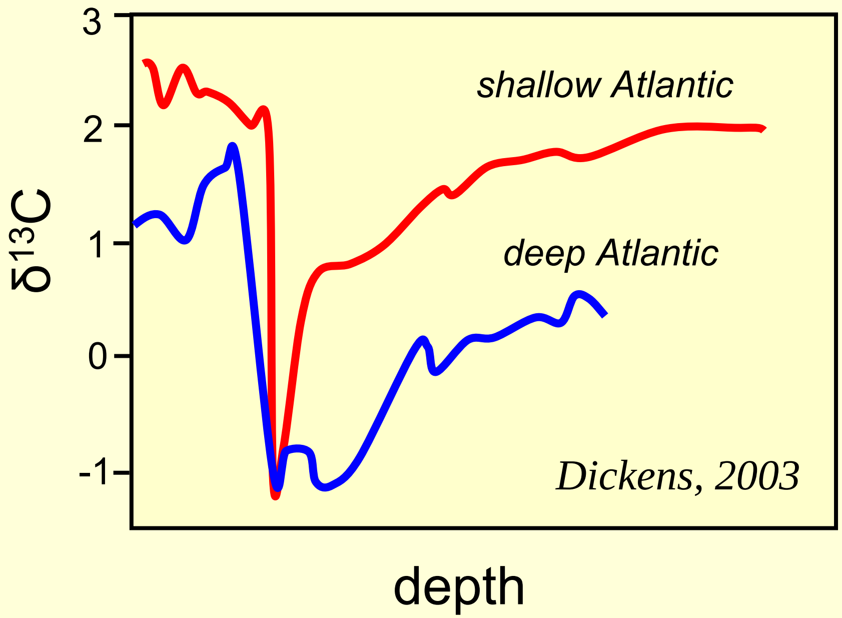
Observation:

Symmetric $\delta^{13}C$ peak superponed on gradual $\delta^{13}C$ shift from about +3 ‰ to 0 ‰.

Single addition of ^{12}C-enriched material to the ocean-atmosphere system: sudden $\delta^{13}C$ drop followed by recovery and asymptotic approach .



Example: Paleocene-Eocene Thermal Maximum



methane hydrate release (warming)

Symmetric $\delta^{13}C$ peak ⇒ sudden release and withdrawal

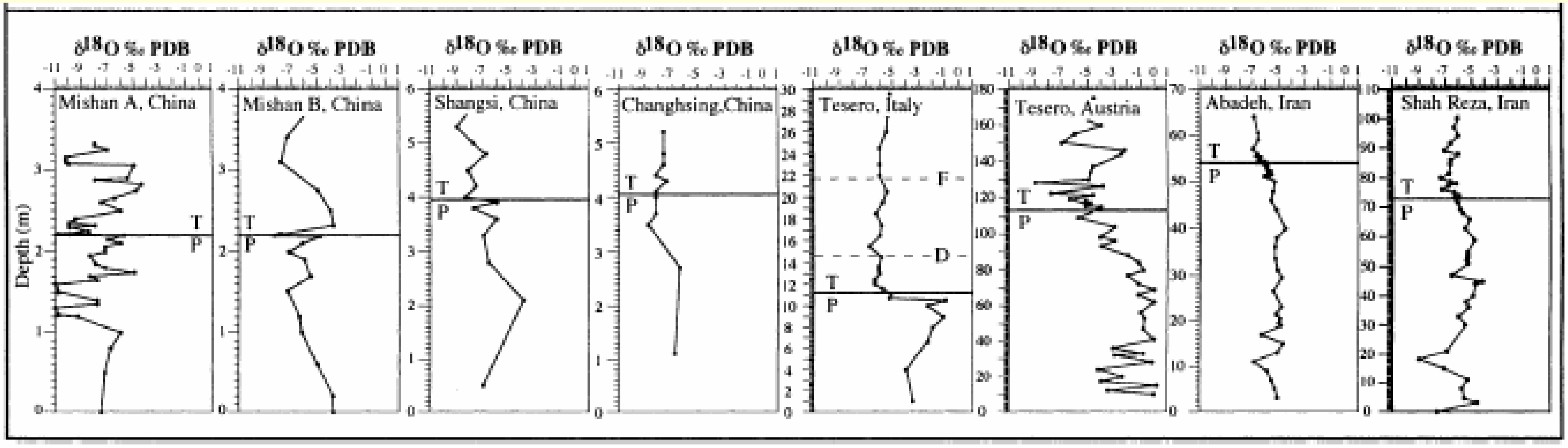
Possible mechanism:

1. Warming - cooling.

Problem:

i) warming is presumed, but cooling isn't,

ii) $\delta^{18}O$ records are not conclusive enough.

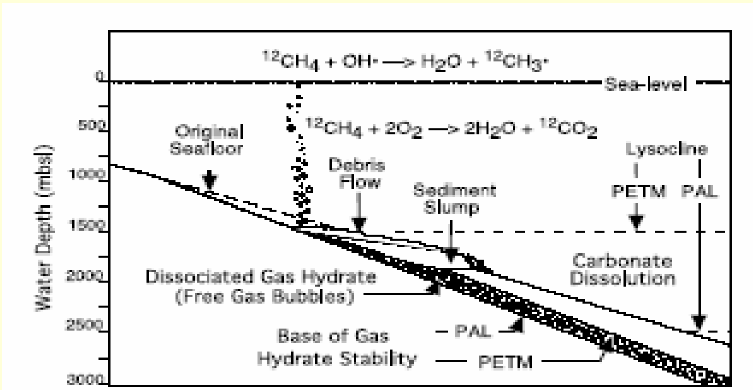


Heydari et al., 2001

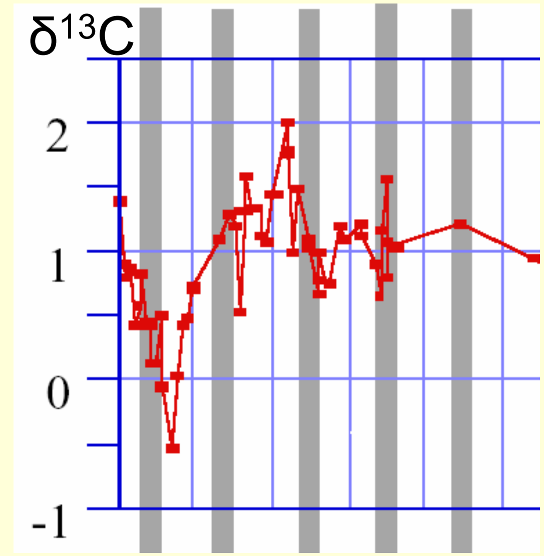
Possible mechanism:

2. Slope sediment failure

Analogue: 15-13 ky event (dated major slope failures, high CH_4 level in ice cores); glacioeustatic transgression.



Dickens, 2003



Causes:

- impact-related shock wave (Berner, 2002)
- igneous activity (Siberian flood basalt) (Svensen et al., 2004)
- rapid transgression (Wignall and Hallam, 1992)

Stable isotope trends across the Triassic-Jurassic boundary at Csövár, Hungary

Based on

Pálfy, J., Demény, A., Haas, J., Hetényi, M., Orchard, M., Vető, I. (2001): Carbon isotope anomaly and other geochemical changes at the Triassic-Jurassic boundary from a marine section in Hungary. Geology, 29, 1047-1050.

József Pálfy, Attila Demény, János Haas, Elizabeth S. Carter, Ágnes Görög, Dóra Halász, Anna Oravecz-Scheffer, Magdolna Hetényi, Emő Márton, Michael J. Orchard, Péter Ozsvárt, István Vető, Norbert Zajzon (2006): Triassic–Jurassic boundary events inferred from integrated stratigraphy of the Csővár section, Hungary. Palaeogeography, Palaeoclimatology, Palaeoecology (in press)

Questions:

- Is the extinction event related to a single process (single $\delta^{13}C$ peak), or to superposition of multiple processes?

- How are the responsible processes reflected by the stable isotope record?

Pálfy et al., 2001

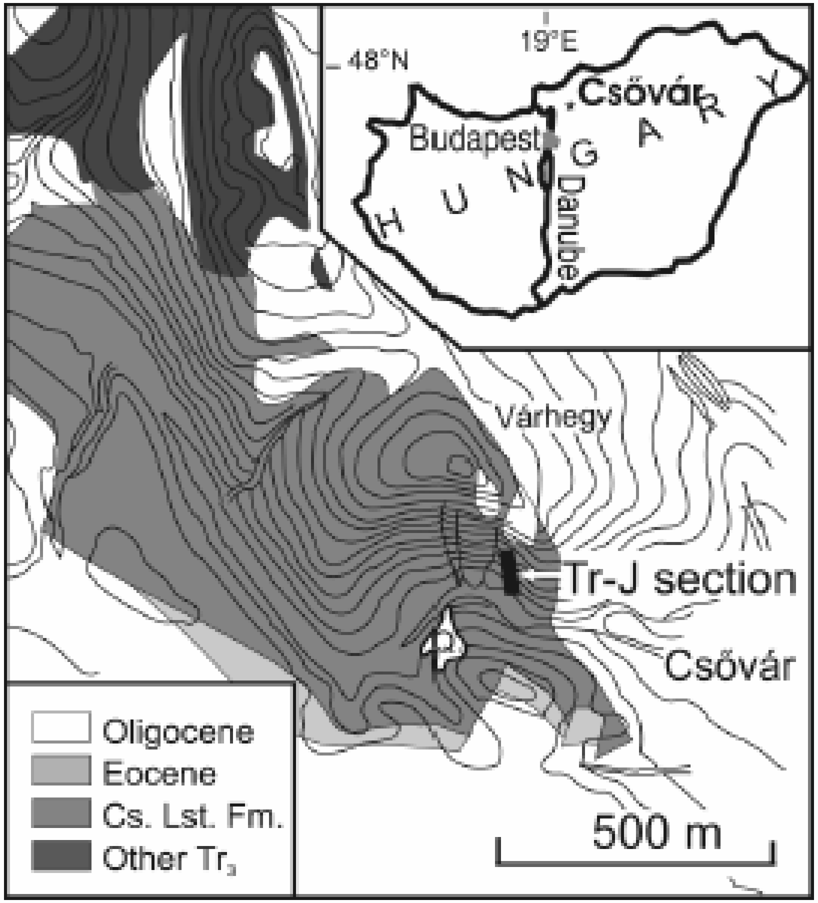
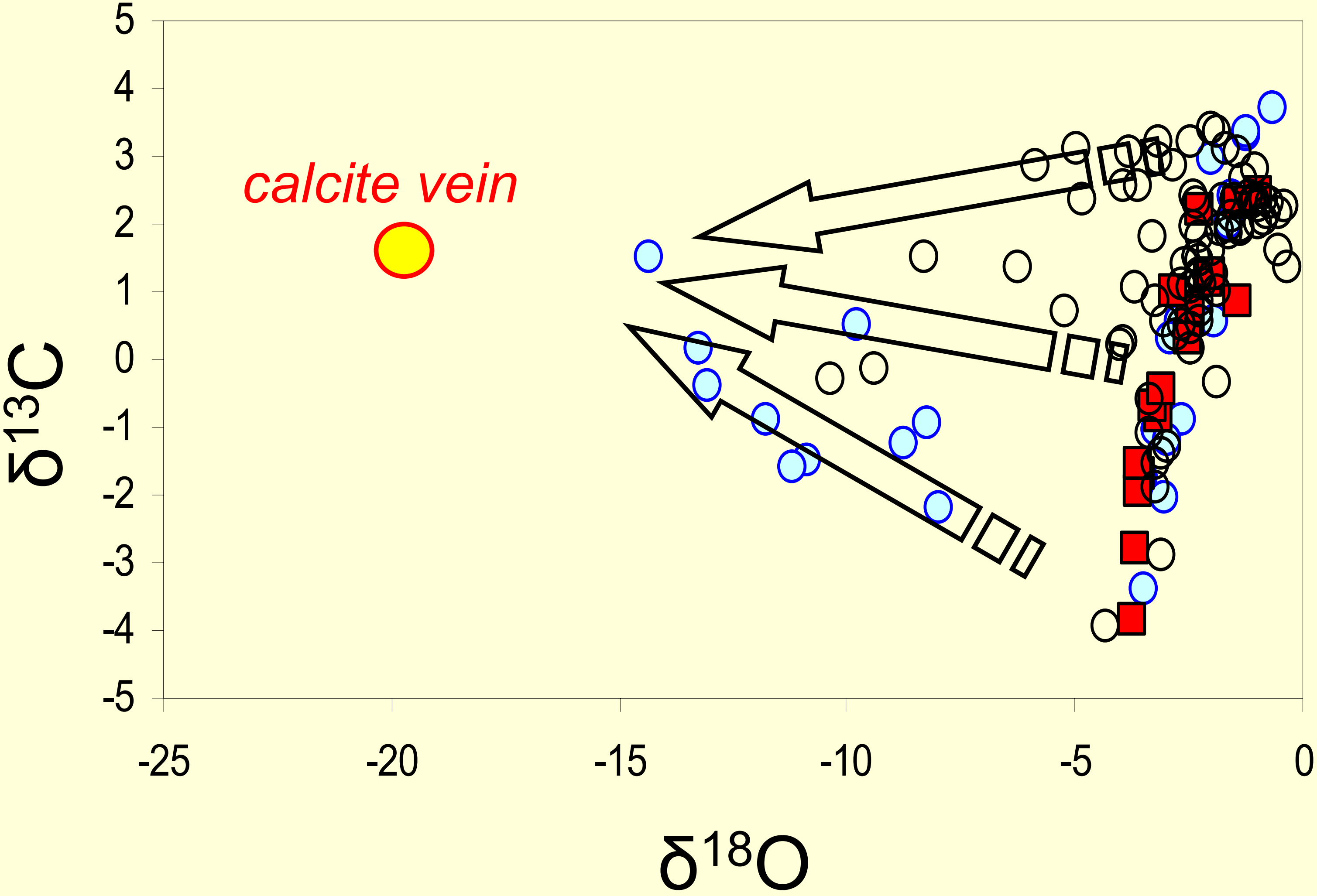
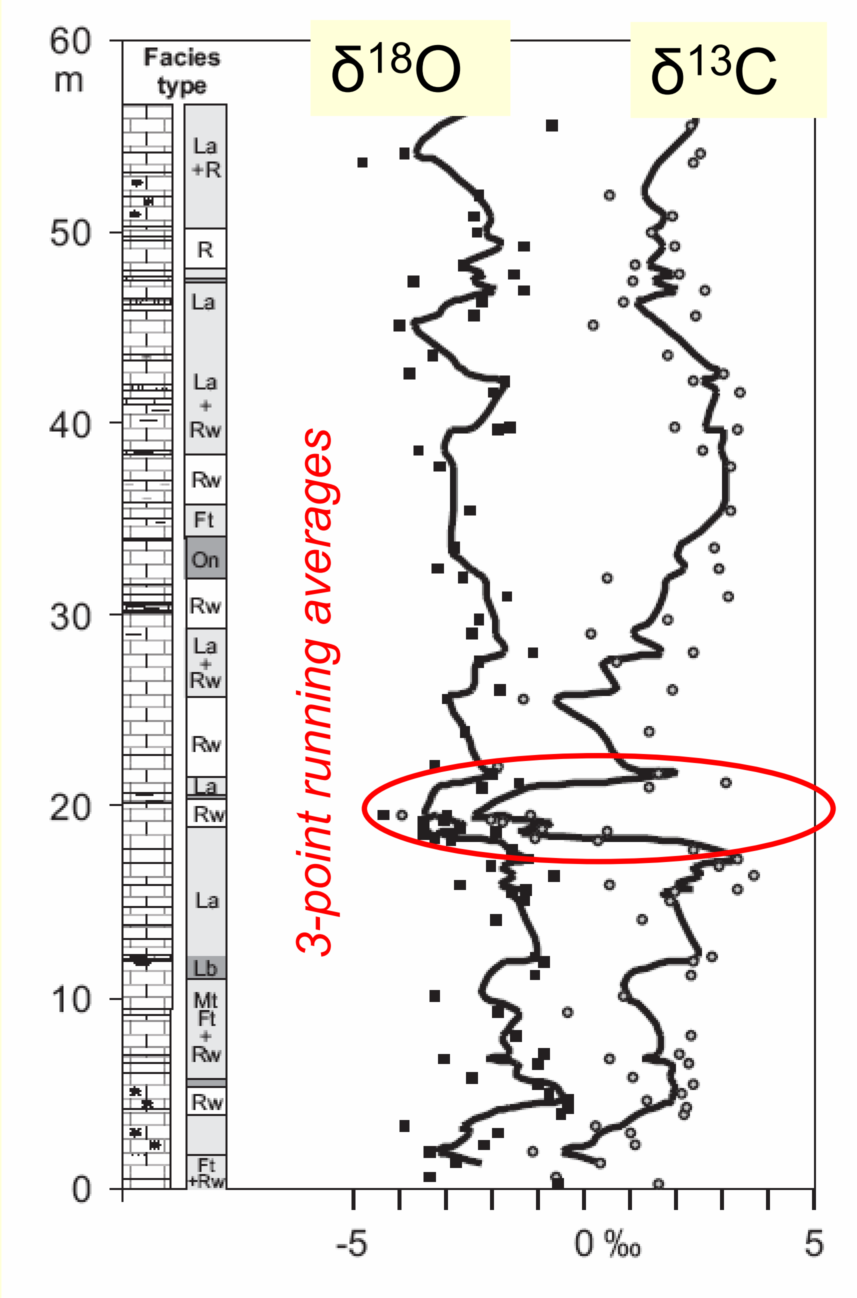


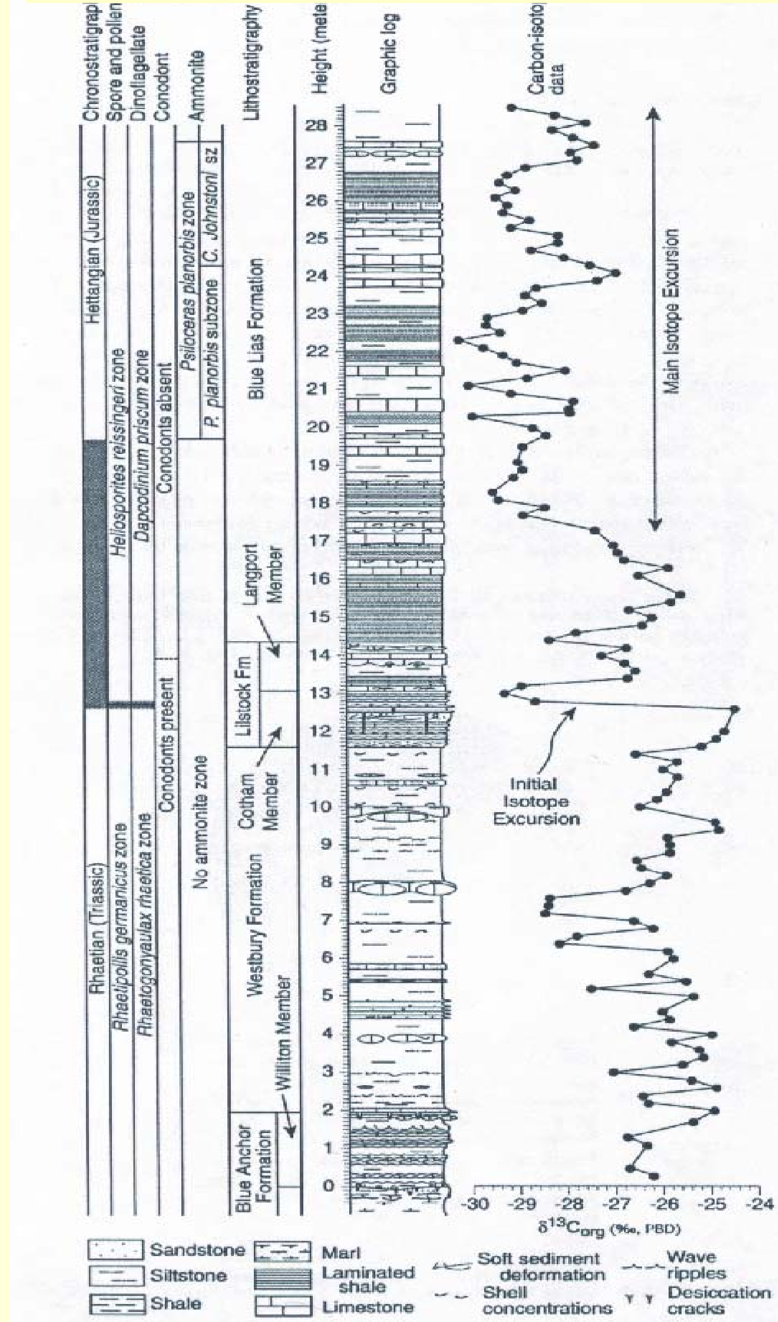
Figure 1. Location of Triassic-Jurassic (Tr-J) boundary section at Csővár. Geology of southeast part of Csővár block is simplified from Benkő and Fodor (2001). Q. is Pokol-völgy quarry; Cs. Lst. Fm. is Csővár Limestone Formation.

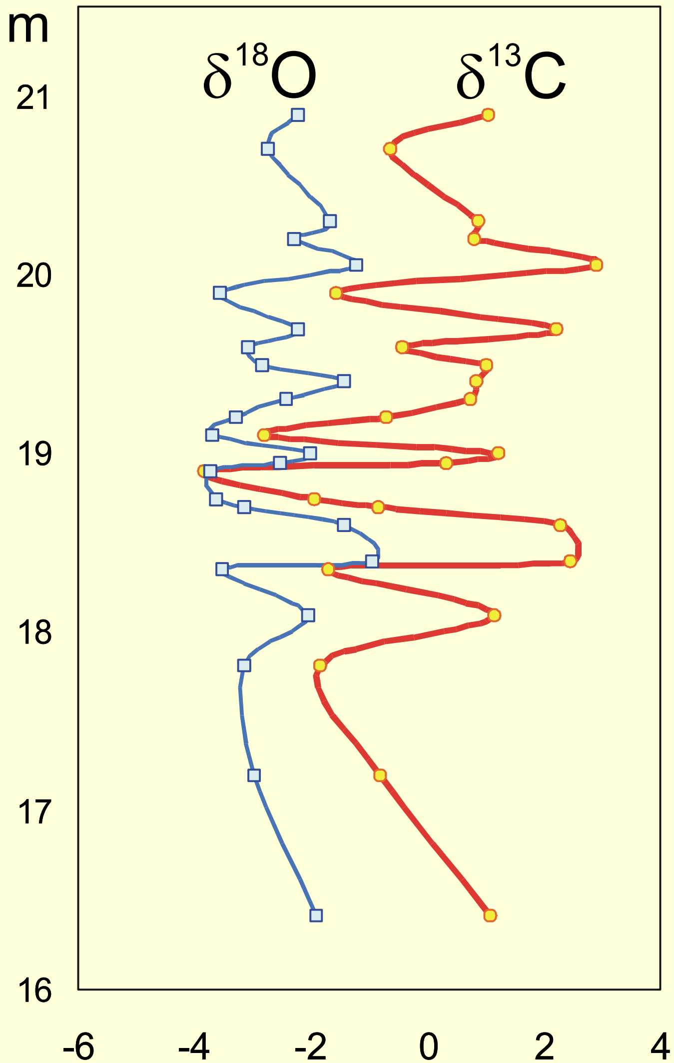
Pálfy et al., 2001


calcite vein
δ13C
δ18O
5
4
3
2
1
0
-1
-2
-3
-4
-5
-25
-20
-15
-10
-5
0

Hesselbo et al., 2002







- Strong fluctuation in $\delta^{13}C$
- Good $\delta^{13}C$-$\delta^{18}O$ correlation

• $\delta^{18}O$ change of –4 ‰ associated with the $\delta^{13}C$ shift ⇒ paleotemperature equations of Shackleton and Kennett (1975), Mulitza et al. (2003), Rosales et al. (2004), Waelbroeck et al. (2005) ⇒ temperatures from 13 to 28 ºC /theoretical seawater $\delta^{18}O$ = –1.2 ‰, Shackleton and Kennett, 1975/.

• Warming of similar magnitude has been documented for the Early Toarcian (Rosales et al., 2004) and was interpreted as a primary signal.

• Thus, the fluctuations at the TJB are not unique and are consistent with a model of thermally-driven episodic methane release.

Conclusions:

- *Late-stage alteration effects were important and modified the original isotope signal in bulk carbonate*

- *The $\delta^{13}C$ „peak” in the boundary layers appear also in the organic matter, so it is not related to alteration*

- *The boundary $\delta^{13}C$ peak consists of several fluctuations correlated with $\delta^{18}O$*

- *The $\delta^{13}C$ and $\delta^{18}O$ changes are best explained by sudden warming and concomitant methane release*

Main conclusion

The carbon isotope variations indicate that the major extinction events were not induced by single effects, but rather related to unfortunate coincidences of different influences perturbing life and the carbon cycle.