De dag die het leven voorgoed veranderde: het verhaal van de meteorietinslag en zijn gevolgen voor de mariene fauna in de Belgische subtropische krijtzee.



Dr. Johan Vellekoop
(KU Leuven & KBIN)

Strandwerkgroep De Panne
De Panne – 16/10/2021

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VUB VRIJE UNIVERSITEIT BRUSSEL

AMGC

fwo Research Foundation Flanders Opening new horizons

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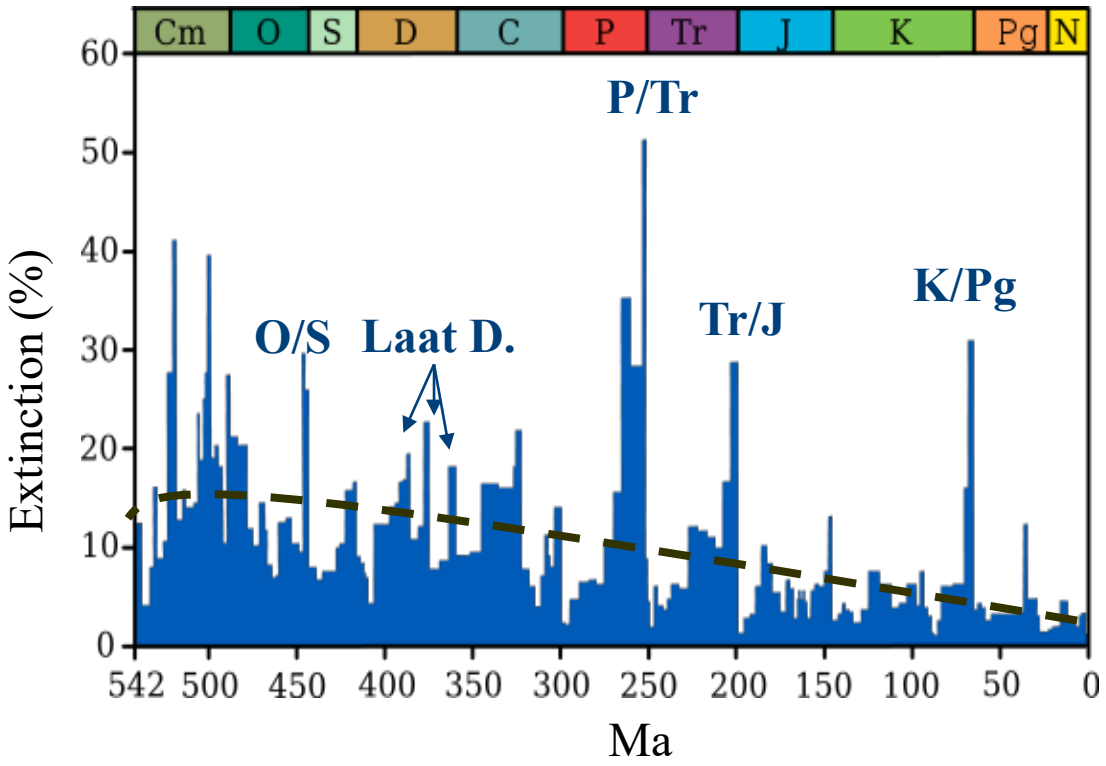
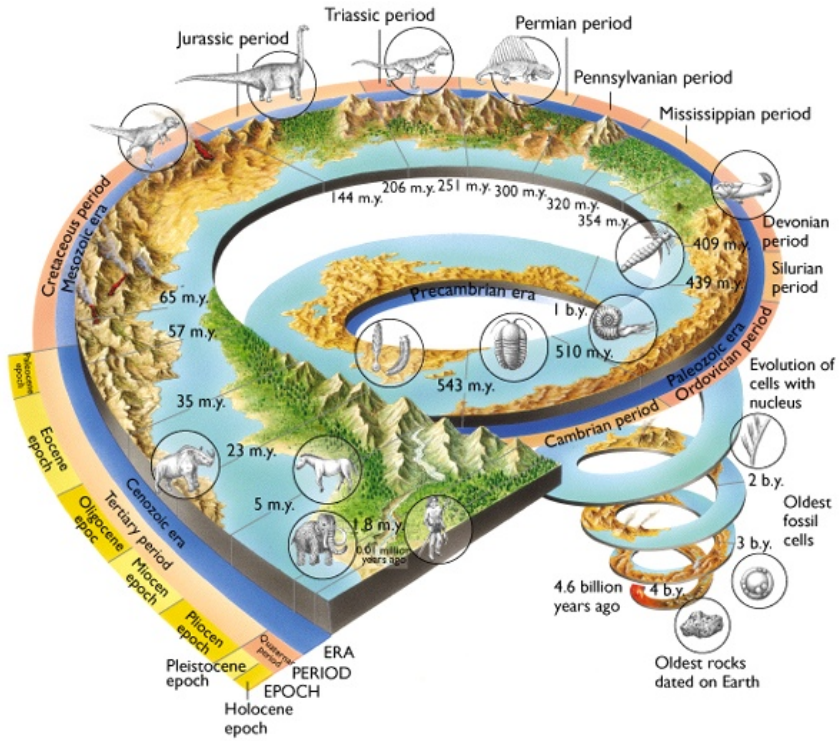
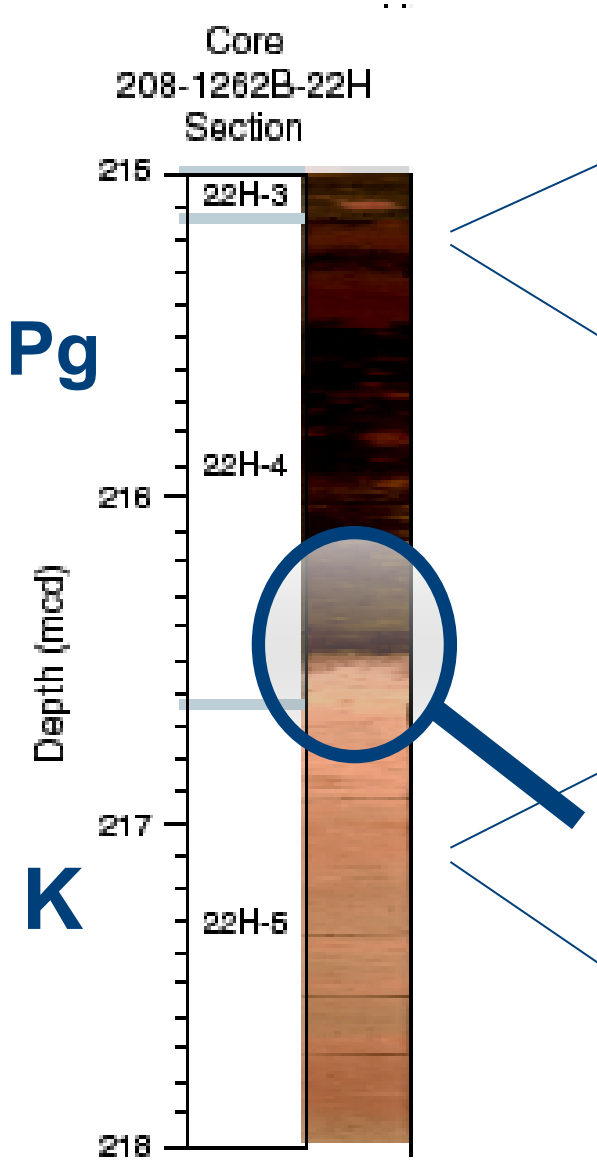
De Krijt-Paleogeengrens

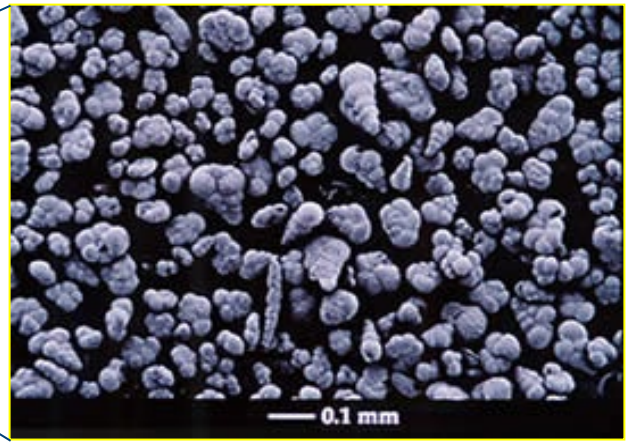
- ± 66.02 miljoen jaar gelden
- De laatste (?) van de Grote Vijf massa extincties





Raup and Sepkoski, 1982 en anderen





Paleocene Foraminifera



Cretaceous Foraminifera

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K/Pg wereldwijd

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Foto's door Smit & Brinkhuis



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6 June 1980, Volume 208, Number 4448 SCIENCE

Extraterrestrial Cause for the Cretaceous-Tertiary Extinction

Experimental results and theoretical interpretation

Luis W. Alvarez, Walter Alvarez, Frank Asaro, Helen V. Michel

extinctions (*3*, *4*), and two recent meetings on the topic (*5*, *6*) produced no sign of a consensus. Suggested causes include gradual or rapid changes in oceanographic, atmospheric, or climatic conditions (*7*) due to a random (*8*) or a cyclical (*9*) coincidence of causative factors; a magnetic reversal (*10*); a nearby supernova (*11*); and the flooding of the ocean surface by fresh water from a postulated arctic lake (*12*).

A major obstacle to determining the cause of the extinction is that virtually all the available information on events at the time of the crisis deals with biological changes seen in the paleontological record and is therefore inherently indirect.

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level for D_0 of 1 and 2 mm. Evidently the data show large real differences in drop size characteristics. They also suggest that use of data from a conventional (single-polarization) radar, with an assumed drop-size distribution, may lead to large errors in computation of localized volumes of high rainfall rate.

The work described here formed part of the research programme of the Rutherford and Appleton Laboratories of the SRC.

Received 28 December 1979; accepted 19 March 1980.

1. Battan, L. J. *Radar Observations of the Atmosphere*, 89–93, 85, 40 (University of Chicago Press, 1973).
2. Seliga, T. A. & Bringi, V. N. *J. appl. Met.* **15**, 69–76 (1976).
3. Pruppacher, H. R. & Beard, K. V. *Q. Jl R. met. Soc.* **96**, 247–256 (1970).
4. Atlas, D. & Ulbrich, C. W. *J. Rech. Atmos.* **8**, 275–298 (1974).
5. Bringi, V. N., Cherry, S. M., Hall, M. P. M. & Seliga, T. A. *Antennas and Propagation* (IEE, Conference Publication 169, London, 1978).
6. Best, A. C. *Q. Jl R. met. Soc.* **76**, 302–311 (1950).
7. Marshall, J. S. & Palmer, W. M. K. *J. Met.* **5**, 165–166 (1948).

An extraterrestrial event at the Cretaceous–Tertiary boundary

J. Smit
Geological Institute, Nieuwe Prinsengracht 130, Amsterdam, Holland

J. Hertogen
Fysico-chemical Geology, St Michielstraat 16, Leuven, Belgium

Closely spaced samples from an uninterrupted calcareous pelagic sequence across the Cretaceous–Tertiary boundary reveal that the extinction of planktonic Foraminifera and nannofossils was abrupt without any previous warning in the sedimentary record, and that the moment of extinction was coupled with anomalous trace element enrichments, especially of iridium and osmium. The rarity of these two elements in the crust of the Earth indicates that an extraterrestrial source, such as the impact of a large meteorite may have provided the required amounts of iridium and osmium.

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De inslag van een asteroïde



- 10km diameter
- 20 km/sec
- 1 * 10^{23} joules energie
- Impact: 100,000,000 x Hiroshima
- krater: ~200km radius

Artist impressie door Johan Vellekoop

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De inslag van een asteroïde



The Impact Scenario
…. aka 'The Alvarez-Smit scenario"

Artist impressie door Johan Vellekoop

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De massa-extinctie op de K-Pg grens



De slachtoffers

- **Op land**
- dinosauriërs
- *Elk landdier >25 kg*

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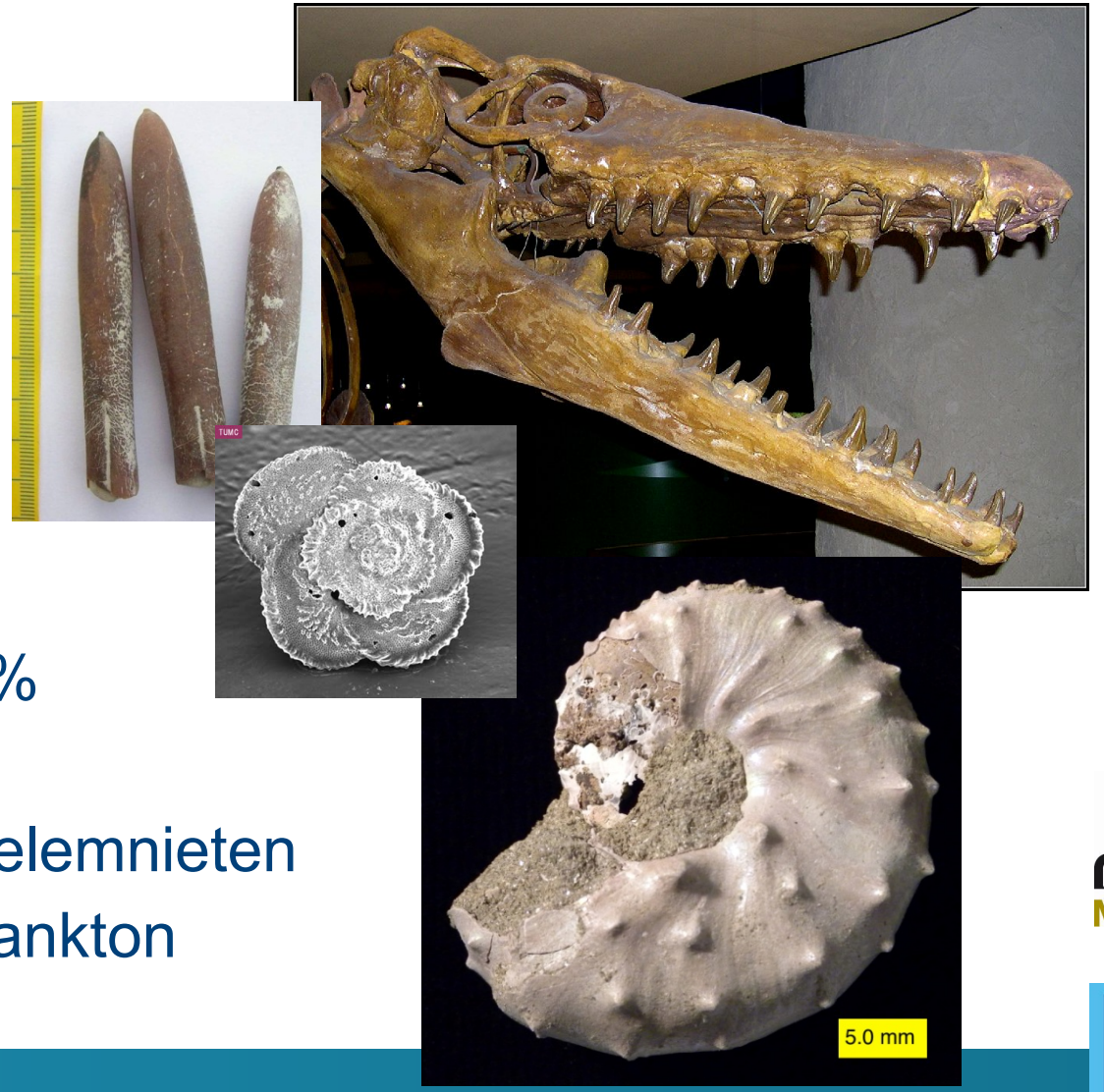
De massa-extinctie op de K-Pg grens

De slachtoffers



- **In de zeeën** ~50 %
- Veel vertebraten
- Ammonieten & Belemnieten
- >75 % van het plankton

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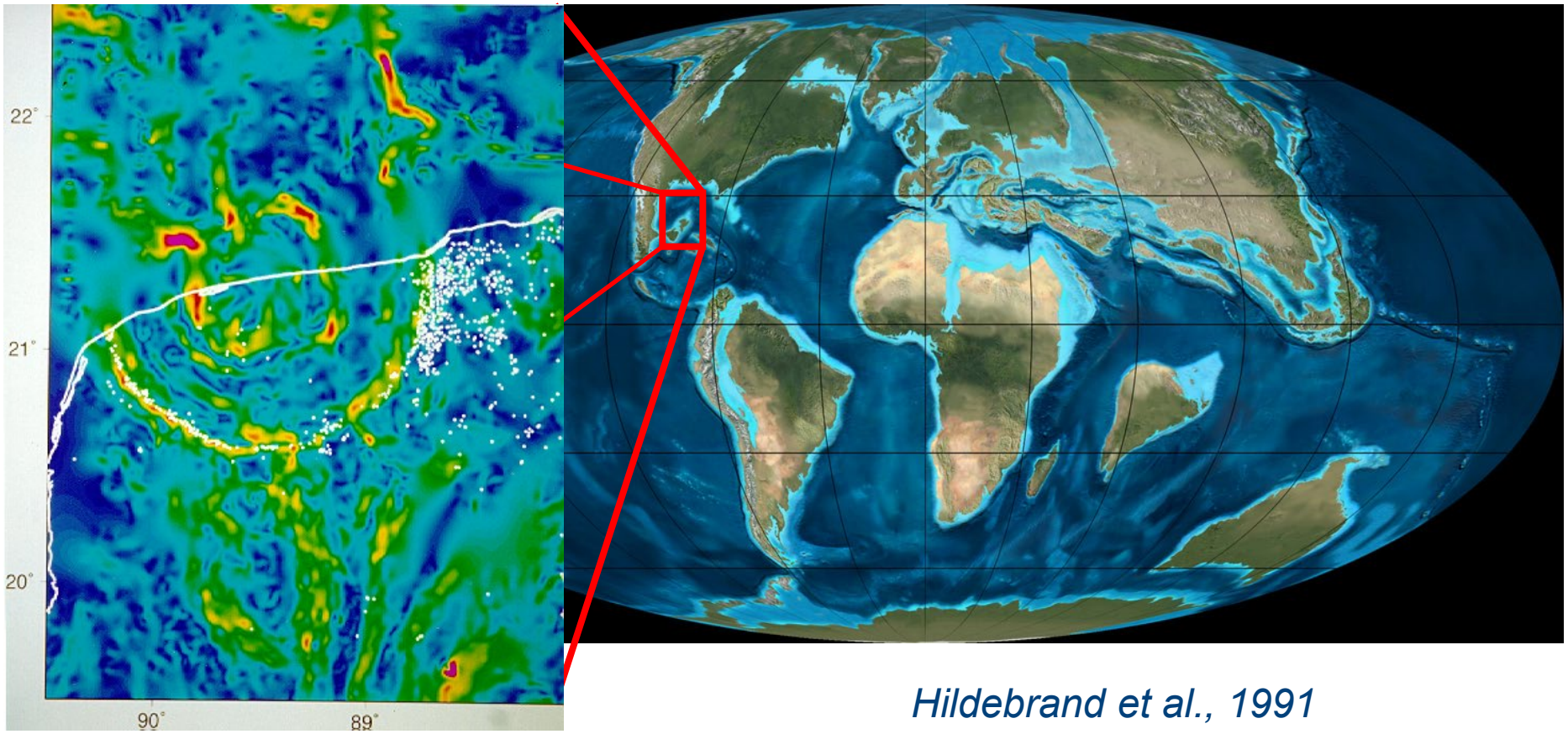
“Smoking gun”

Chicxulub, mexico



Hildebrand et al., 1991

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De inslag van een asteroïde



Waarom een massa-extinctie?

Artist impressie door Johan Vellekoop

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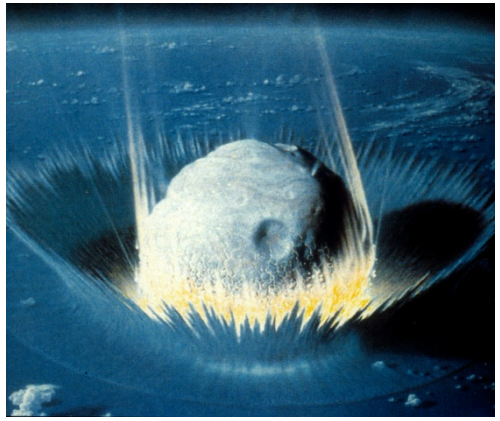
De gevolgen van een inslag

- Verschillende tijdschalen:
  - **binnen 1 dag** (schokgolf, tsunami's etc.)
  - **weken tot decennia** (zure regen, "inslag winter", mega orkanen)
  - **eeuwen tot millennia** (klimaatverandering, etc.)
  - **miljoenen jaren** (biologisch herstel, C-cyclus respons…)



e.g. Kring, 2007

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De gevolgen van een inslag



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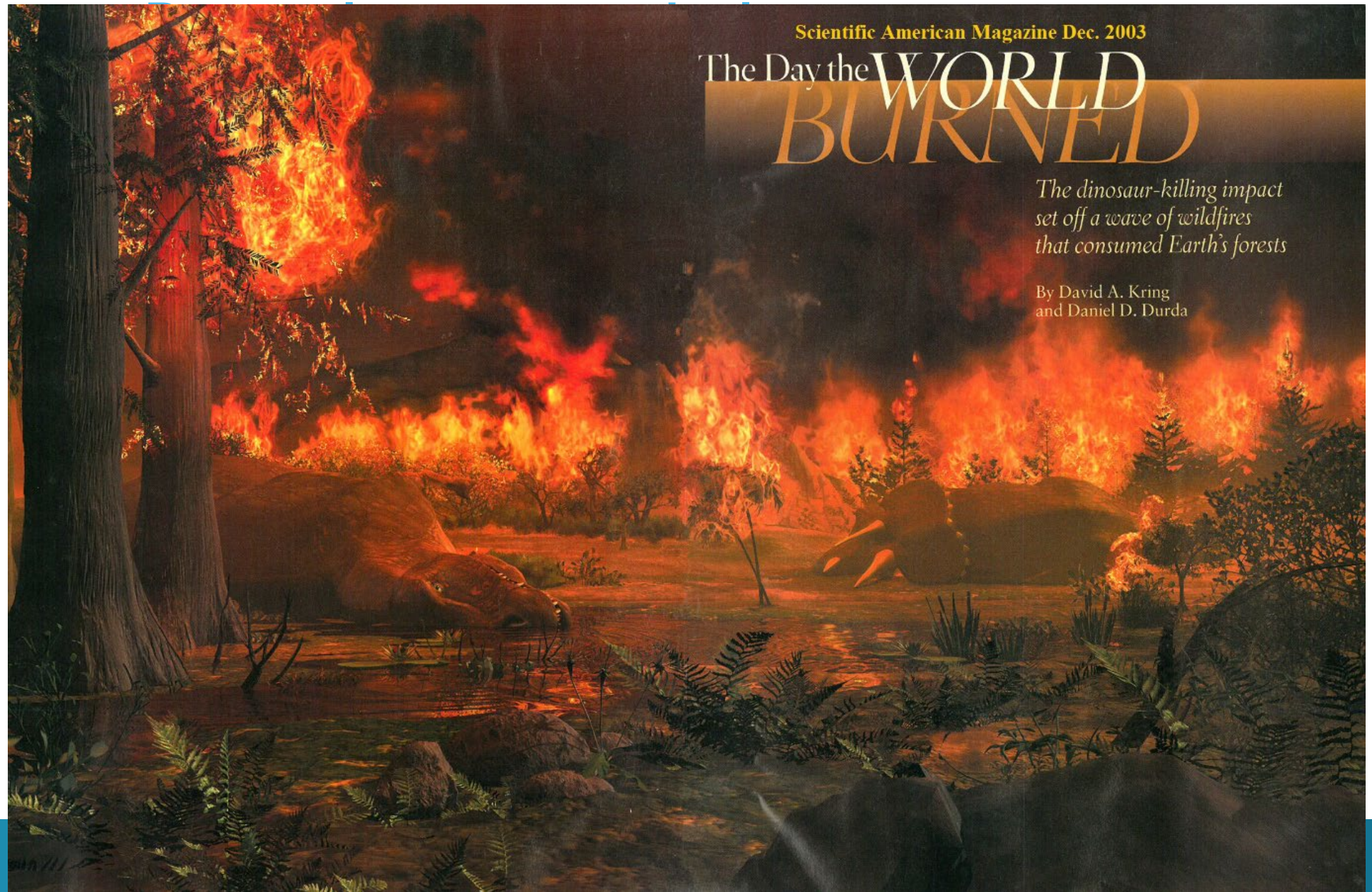

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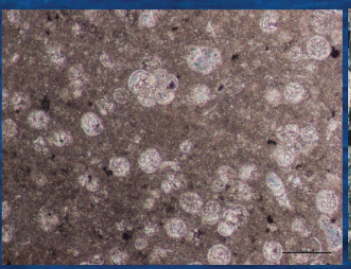
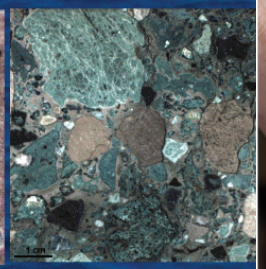
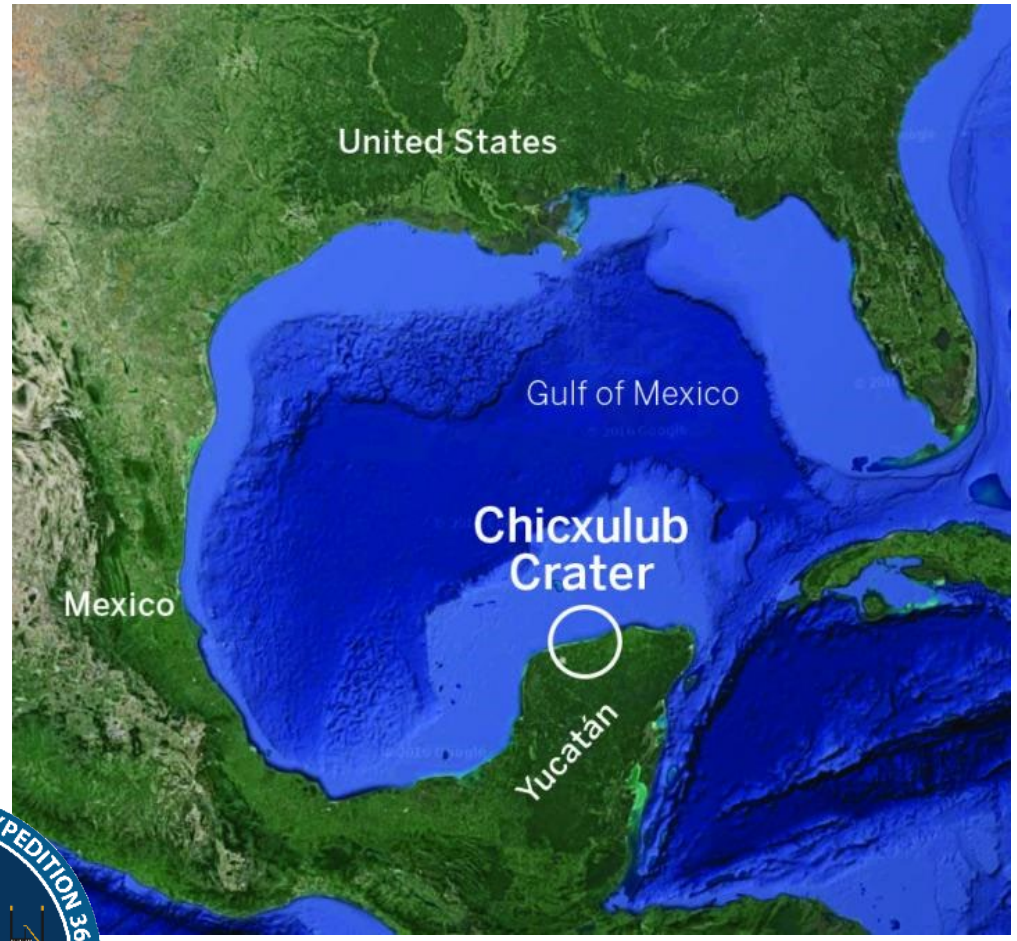
Chicxulub inslagkrater, Mexico











Gulick et al., 2019

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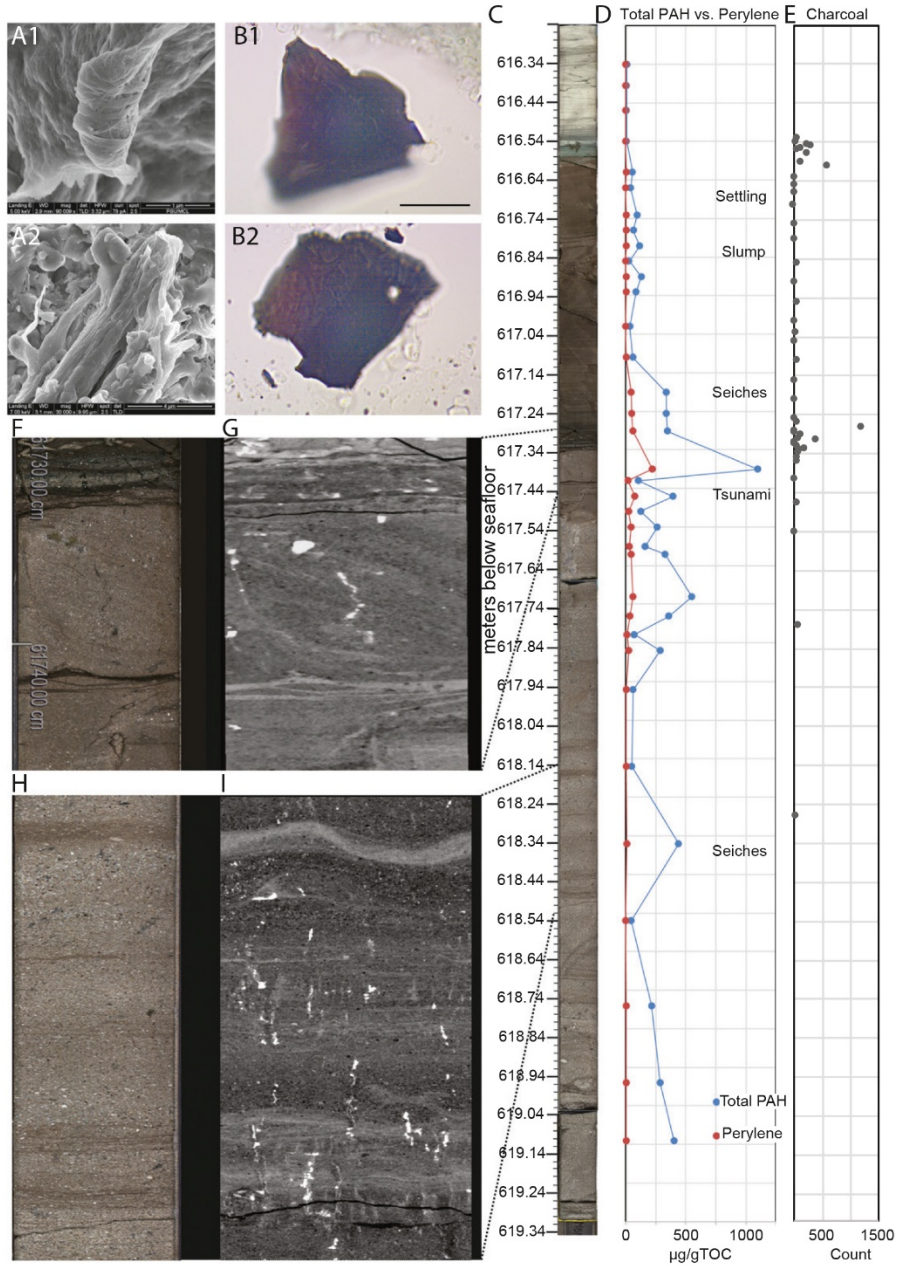

“Fireball stage”

- Houtskoolresten in de Chicxulub krater

Gulick et al., 2019

De tsunami



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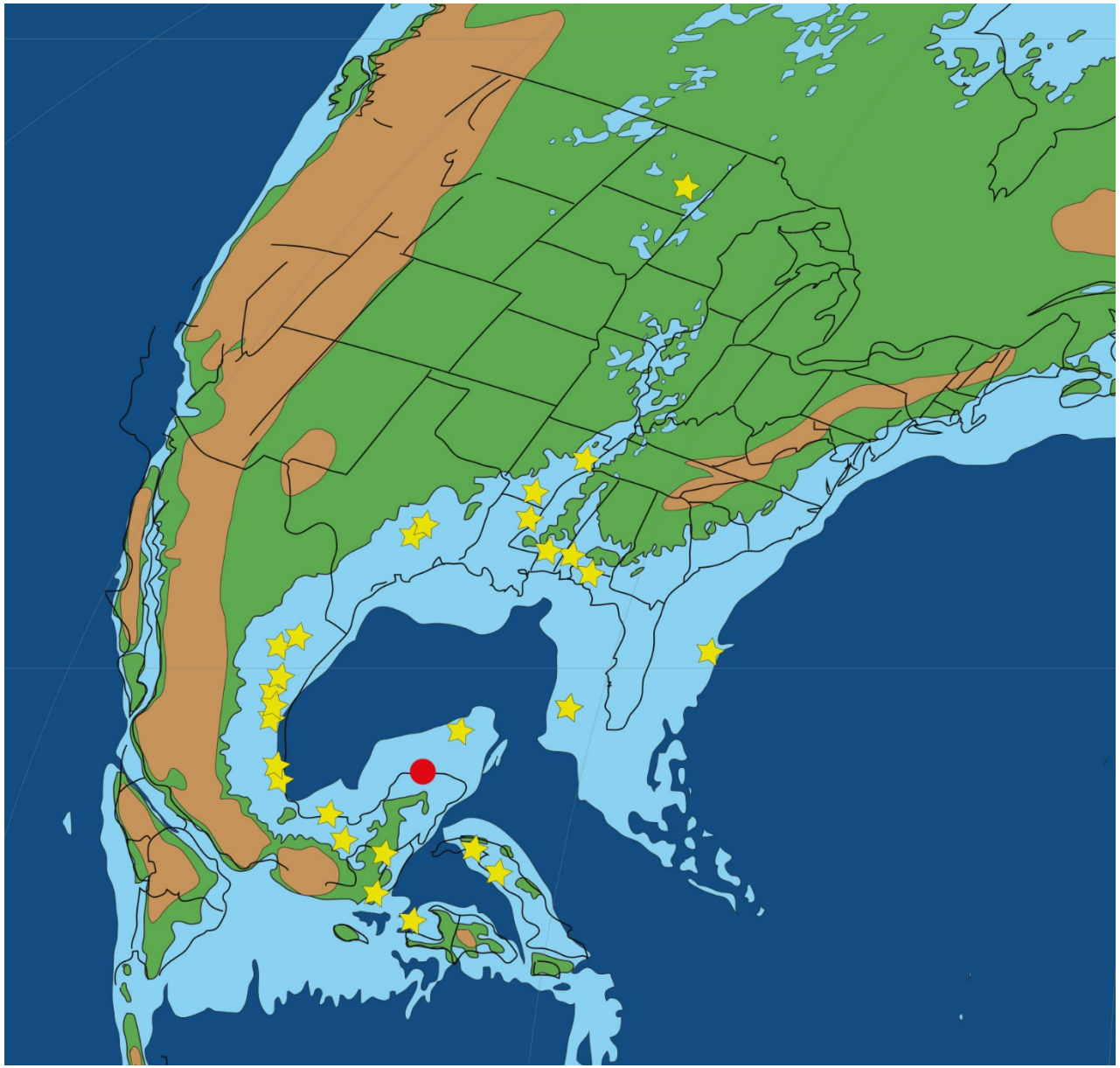
Model door Range et al.

The Tsunami



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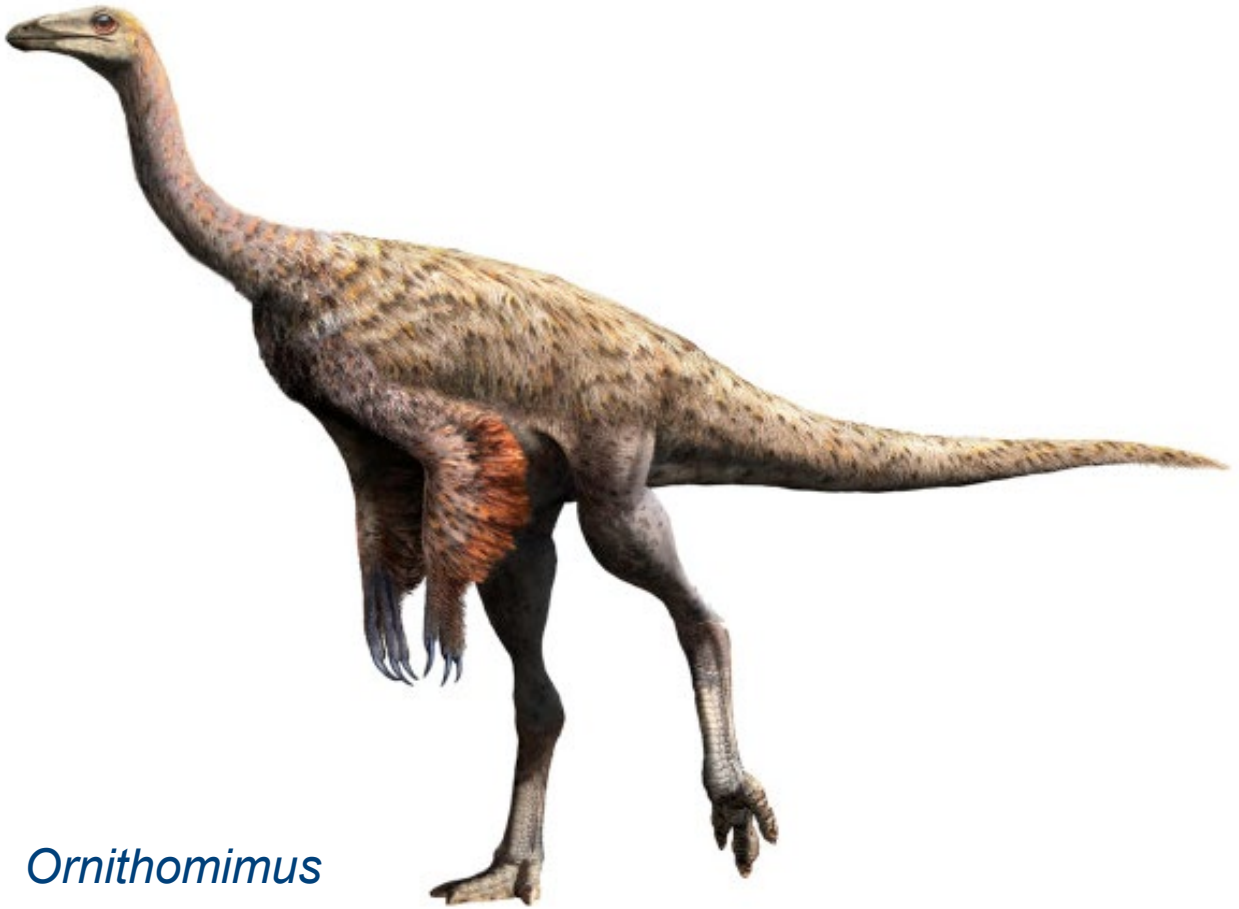
Vellekoop *et al.*, 2014

Popa, Mexico





Ornithomimus

Foto: Jan Smit

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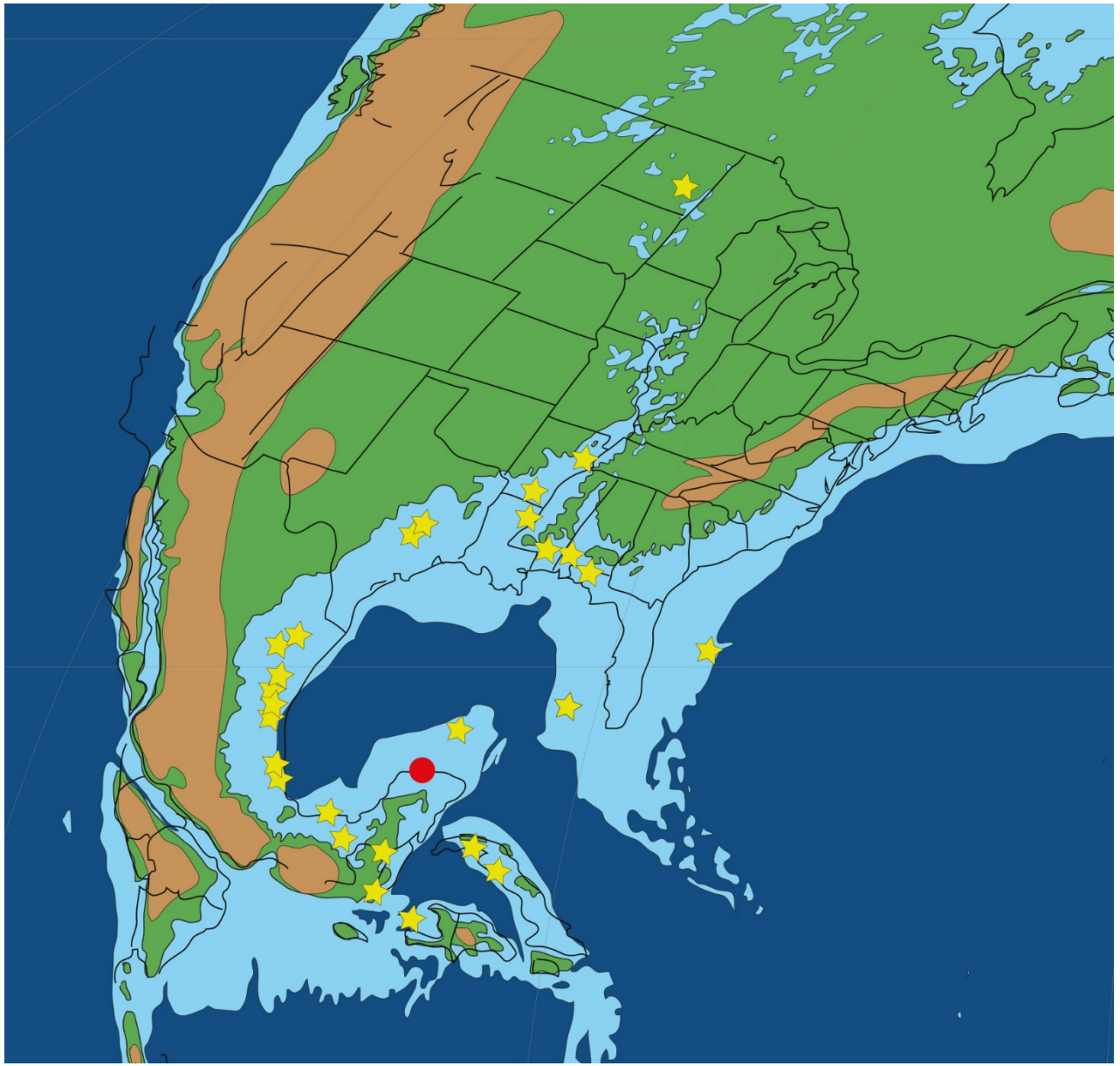
The Tsunami



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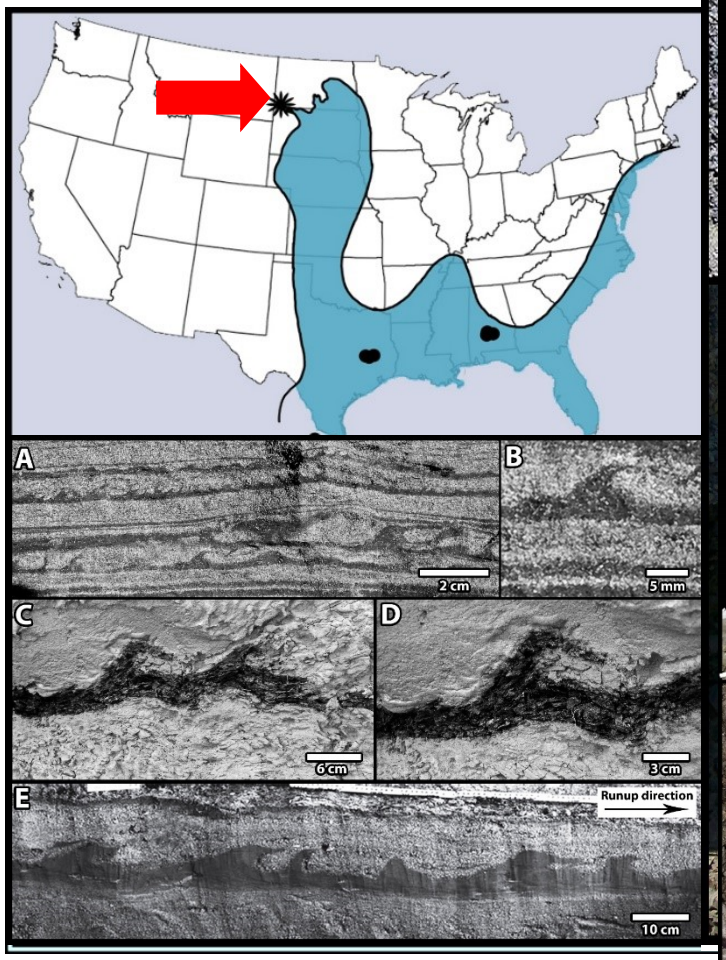
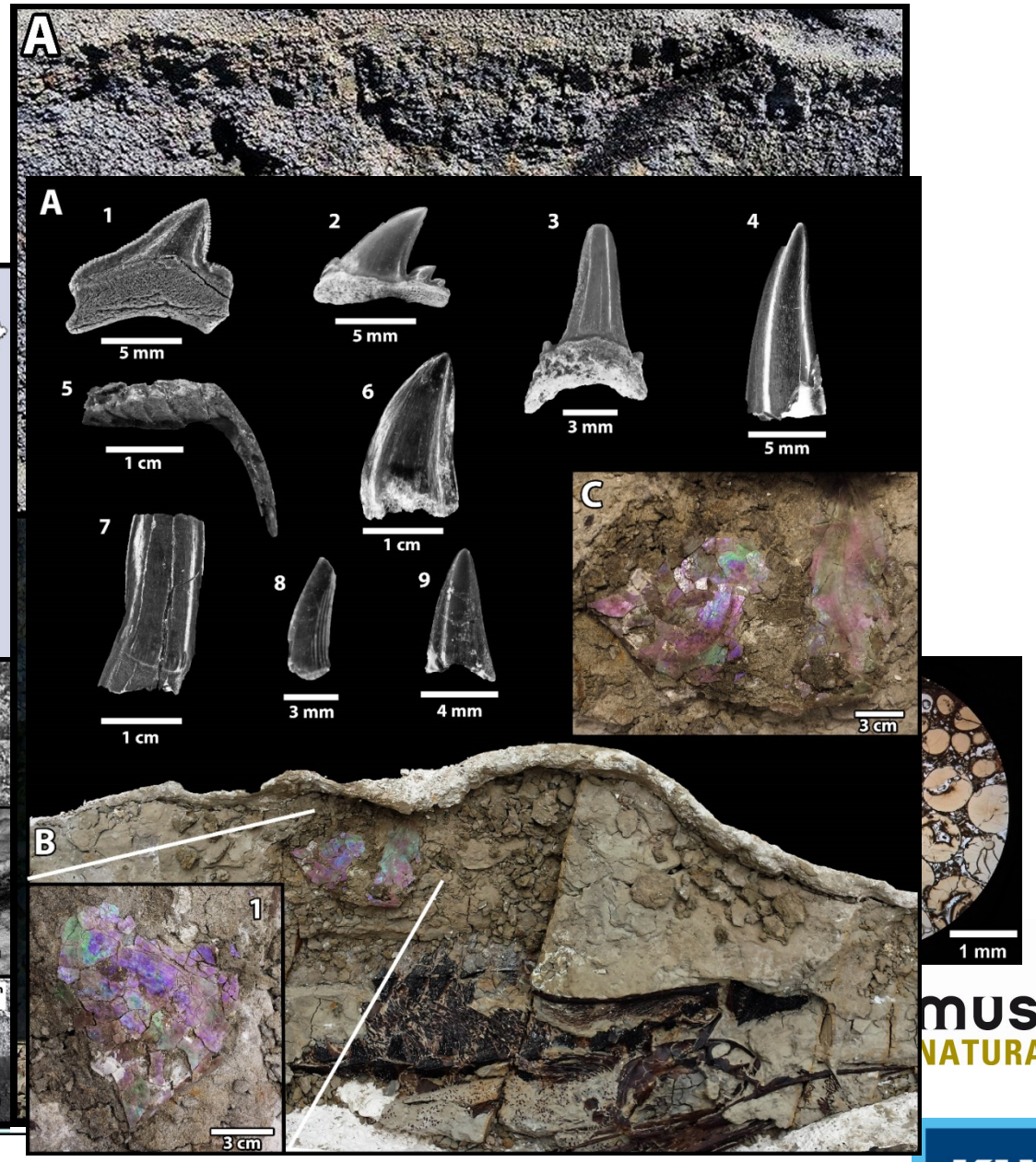
Vellekoop *et al.*, 2014

The Tsunami





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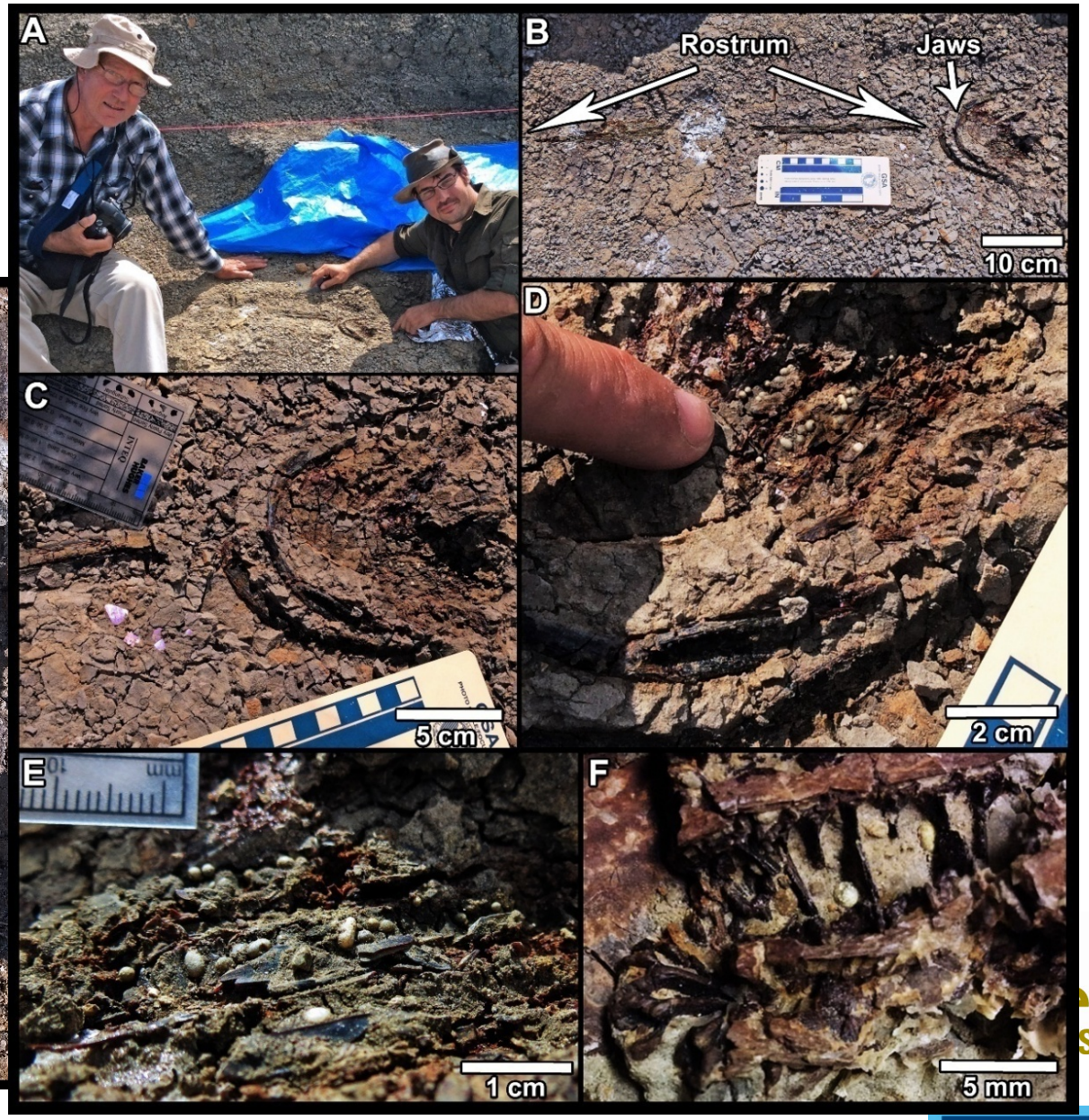
DePalma *et al.* 2019

The Tsunami





De gevolgen van een inslag

Langetermijn gevolgen



- Stofwolk in de atsmosfeer: ‘inslag winter’

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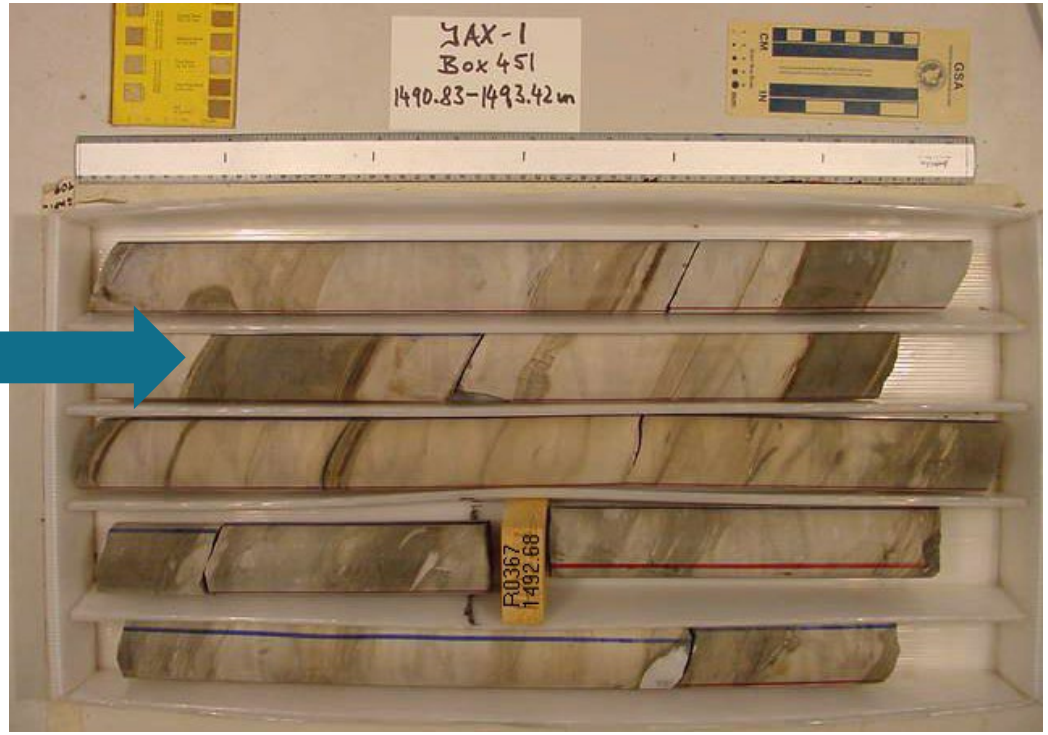
“inslag winter”

Verdampte gesteentelagen:

- stof
- roet
- zwavel aerosolen

Gips ($CaSO_4$)



AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER
10.1002/2016GL072241

Baby, it’s cold outside: Climate model simulations of the effects of the asteroid impact at the end of the Cretaceous

Julia Brugger[1,2,3], Georg Feulner[1,3], and Stefan Petri[1]

[1]Earth System Analysis, Potsdam Institute for Climate Impact Research, Potsdam, Germany, [2]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany, [3]Berlin-Brandenburg Institute of Advanced Biodiversity Research, Berlin, Germany

Key Points:
- We use a coupled climate model to investigate the effects of sulfate aerosols and carbon dioxide from the Chicxulub impact
- We find severe cooling suggesting a major role of the impact in the mass extinction event
- Surface cooling of the ocean results in vigorous mixing which could have caused a plankton bloom

Correspondence to:
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feulner@pik-potsdam.de

Citation:
Brugger, J., G. Feulner, and S. Petri (2016), Baby, it’s cold outside: Climate model simulations of the effects of the asteroid impact at the end of the Cretaceous, *Geophys. Res. Lett.*, *44*, doi:10.1002/2016GL072241.

Abstract Sixty-six million years ago, the end-Cretaceous mass extinction ended the reign of the dinosaurs. Flood basalt eruptions and an asteroid impact are widely discussed causes, yet their contributions remain debated. Modeling the environmental changes after the Chicxulub impact can shed light on this question. Existing studies, however, focused on the effect of dust or used one-dimensional, noncoupled atmosphere models. Here we explore the longer-lasting cooling due to sulfate aerosols using a coupled climate model. Depending on aerosol stratospheric residence time, global annual mean surface air temperature decreased by at least 26°C, with 3 to 16 years subfreezing temperatures and a recovery time larger than 30 years. The surface cooling triggered vigorous ocean mixing which could have resulted in a plankton bloom due to upwelling of nutrients. These dramatic environmental changes suggest a pivotal role of the impact in the end-Cretaceous extinction.

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“inslag winter”

- Atmosfeer: 0.25 Mt zwavel
- Pinatubo (1991): 20 Mt S. (0.5^{o} C afkoeling over 1 jaar)
- De grootste prehistorische eruptie (Toba, Sumatra): ongeveer 1000 Mt S
- Chicxulub: >100.000 Mt zwavel, als aerosolen in atsmosfeer

➢ **1-10 jaar van afkoeling en schemering**

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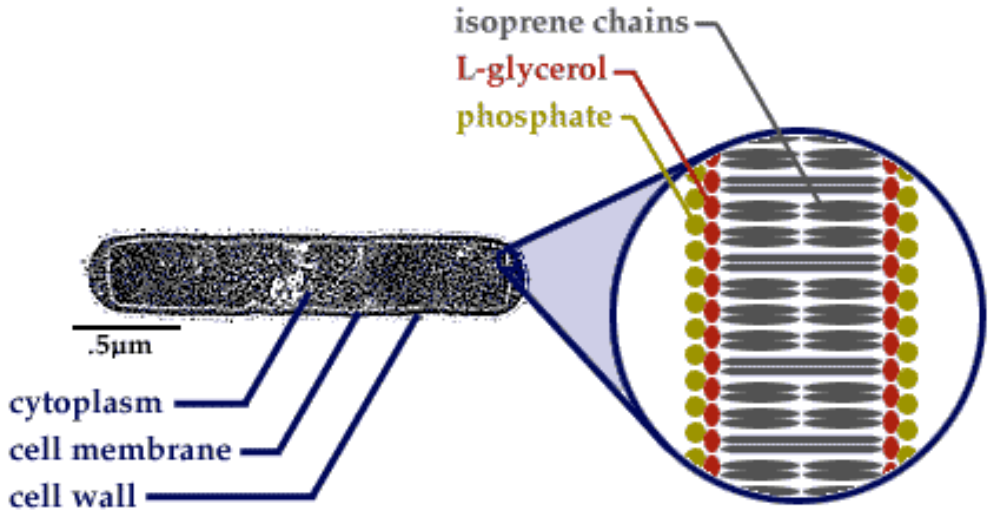
Pope et al., 1997; Kaiho et al., 2016; Brugger et al., 2017

Bewijzen: TEX_{86}-paleothermometer

- **TEX_{86}: zeewater temperatuur**
  - Gebaseerd op celmembranen van *Thaumarcheota*
  - *Door temperatuur bepaald*



Schouten et al., 2002;

Kim et al., 2010

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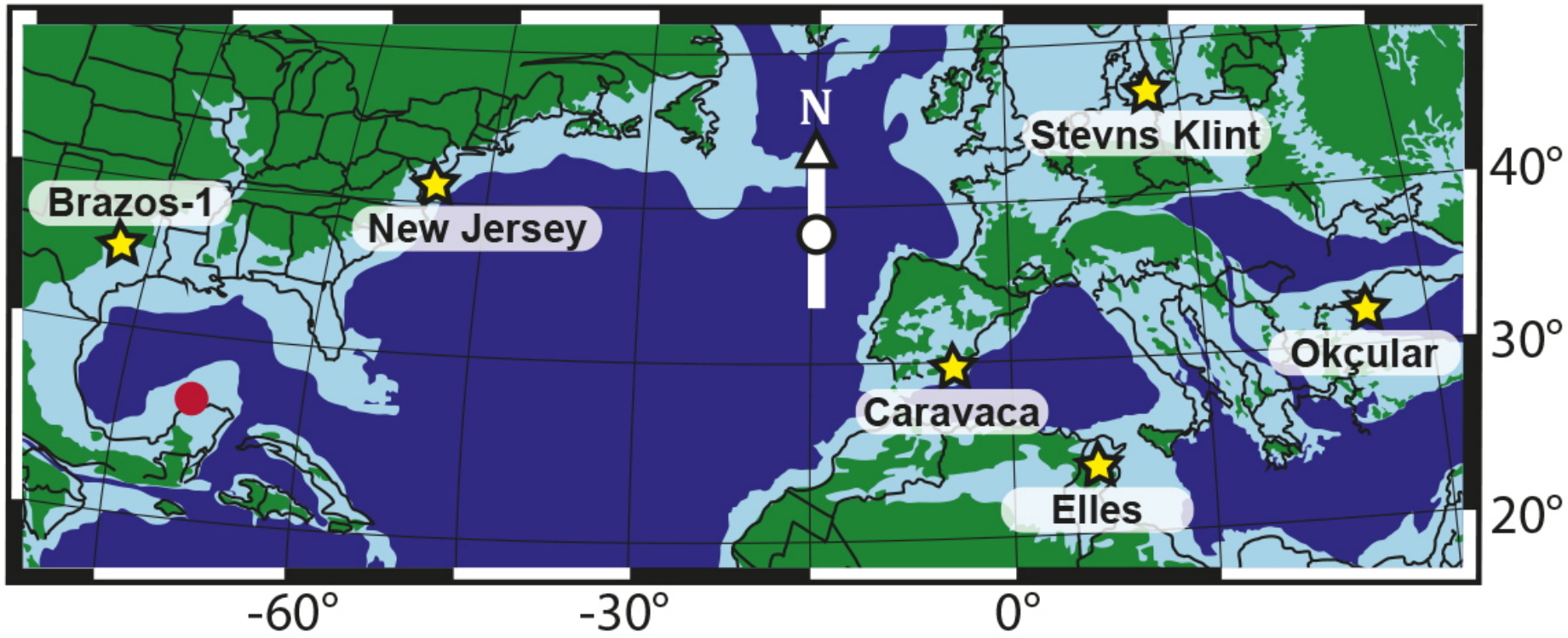
Bestudeerde records



Vellekoop *et al.*, 2014, 2016, 2018

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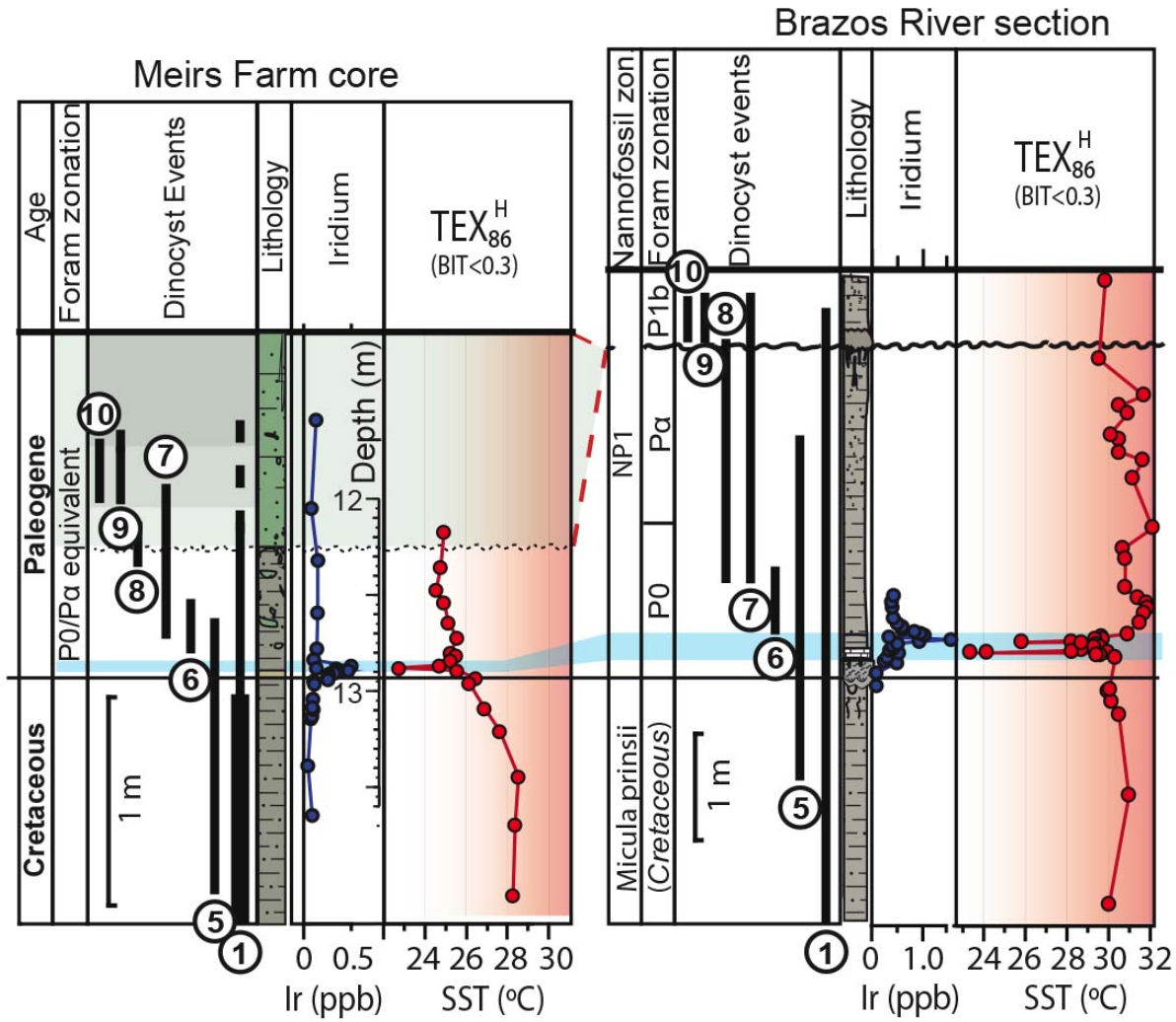
TEX_{86}-records van een “inslag winter”



TEX_{86} paleothermometer

- Zeewater temperatuur
- **Wereldwijde afkoeling** die samenvalt met de ejecta laag

➢ **wereldwijde “inslag winter”!**

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Vellekoop *et al.*, 2014, 2016

De gevolgen van een inslag

Langetermijn gevolgen:



- Na het neer dwarrelen van het stof…….

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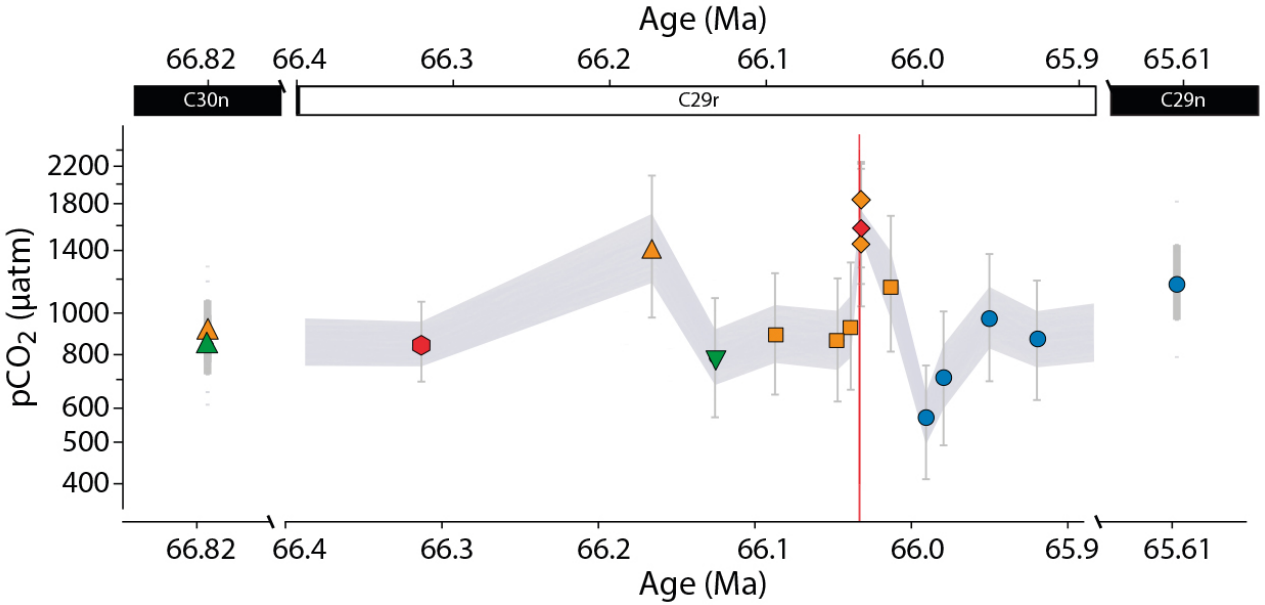
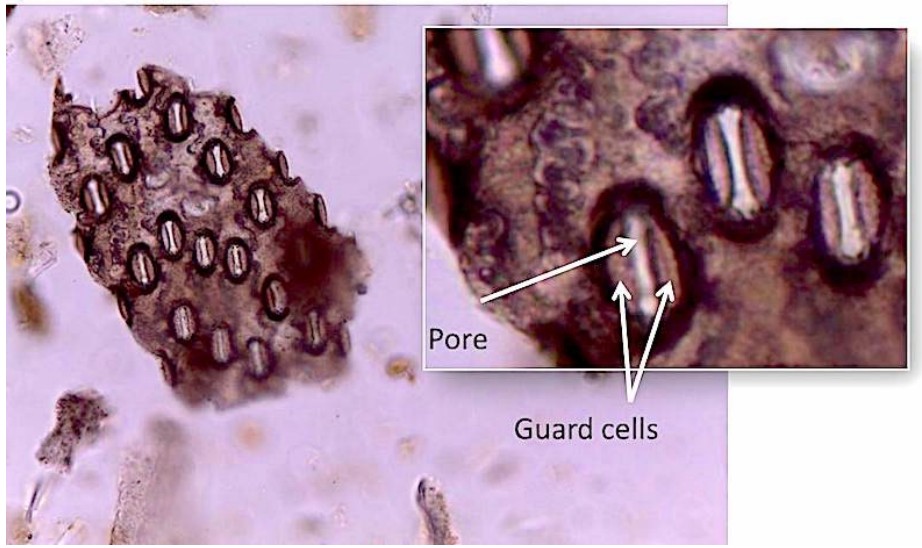
De gevolgen van een inslag

Nog meer langetermijn gevolgen….

- **500-10,000 Gt CO_2** vrijgekomen uit carbonaat-platform
- **>1000 Gt CO_2** vrijgekomen door de verbranding van organisch materiaal





Henehan *et al.*, 2019

Beerling *et al.* 2002

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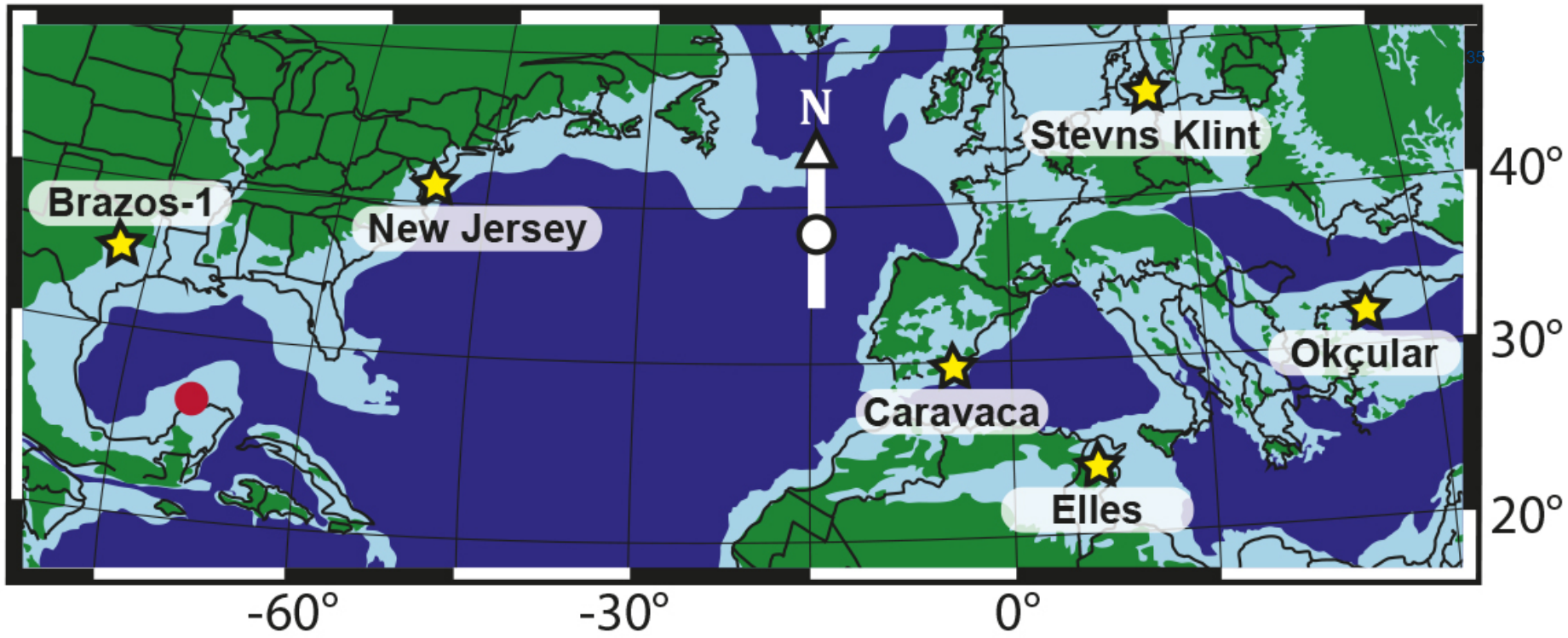
Opwarming na de inslag



Vellekoop *et al.*, 2014, 2016, 2018

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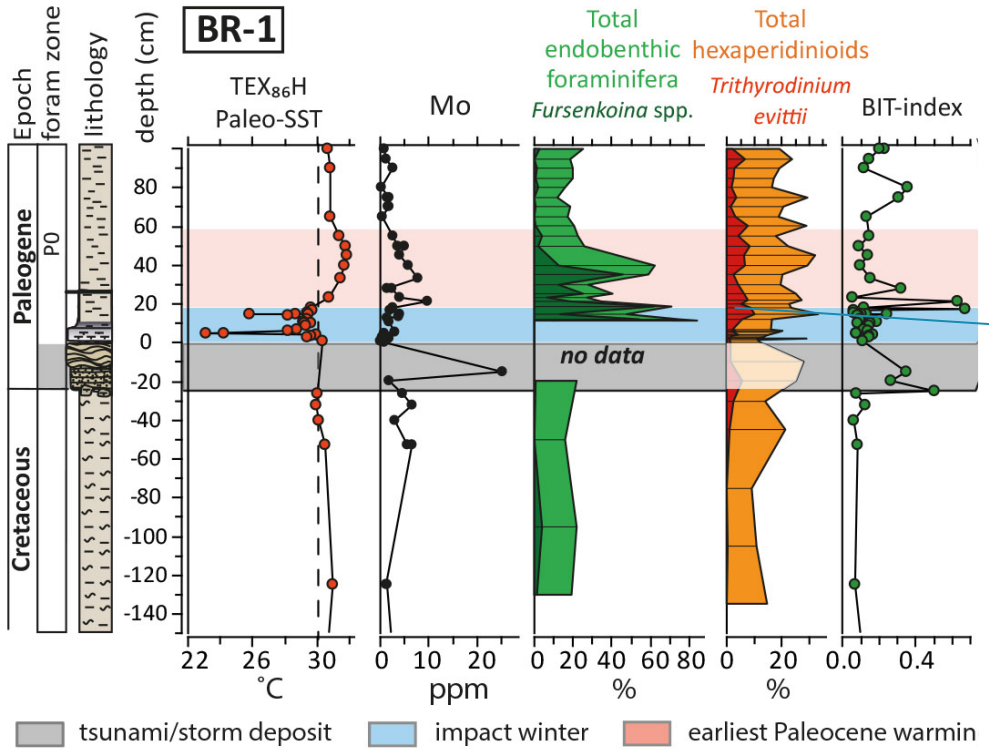
Opwarming na de islag



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temperaturen ~1.5-2 °C boven Krijt-gemiddelde

Vellekoop *et al.*, 2018

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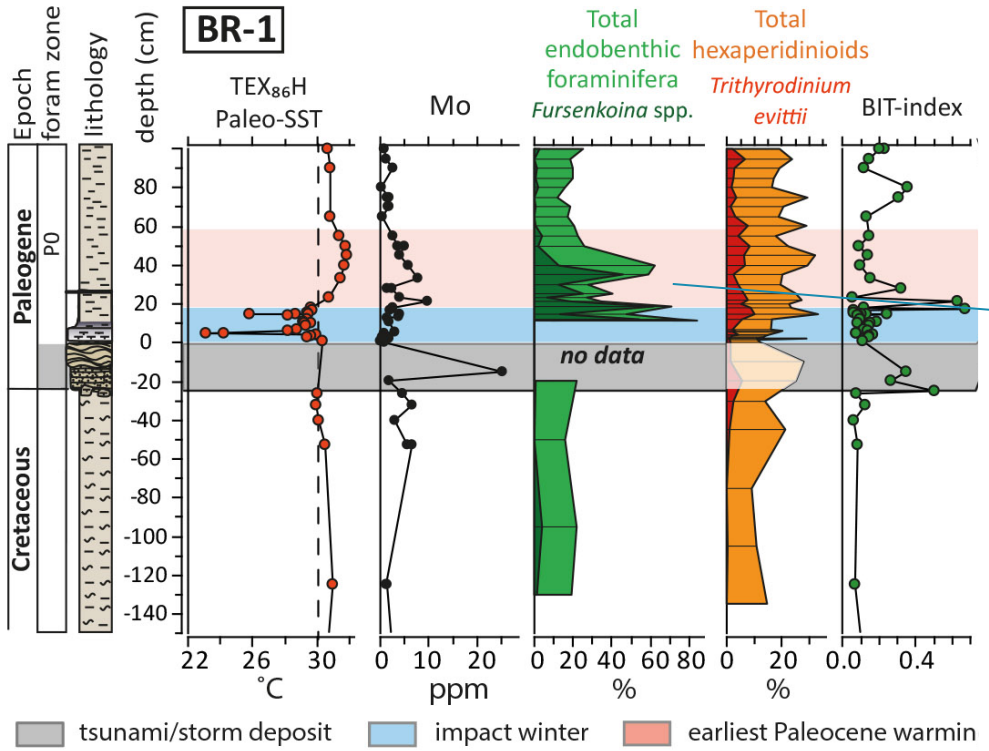
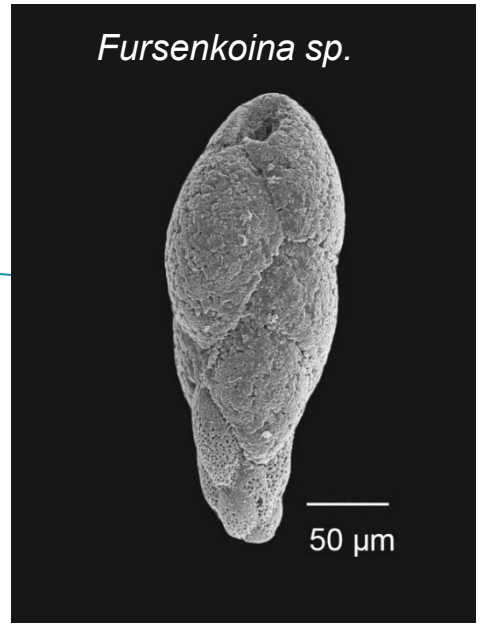
Opwarming na de islag





Vellekoop *et al.*, 2018

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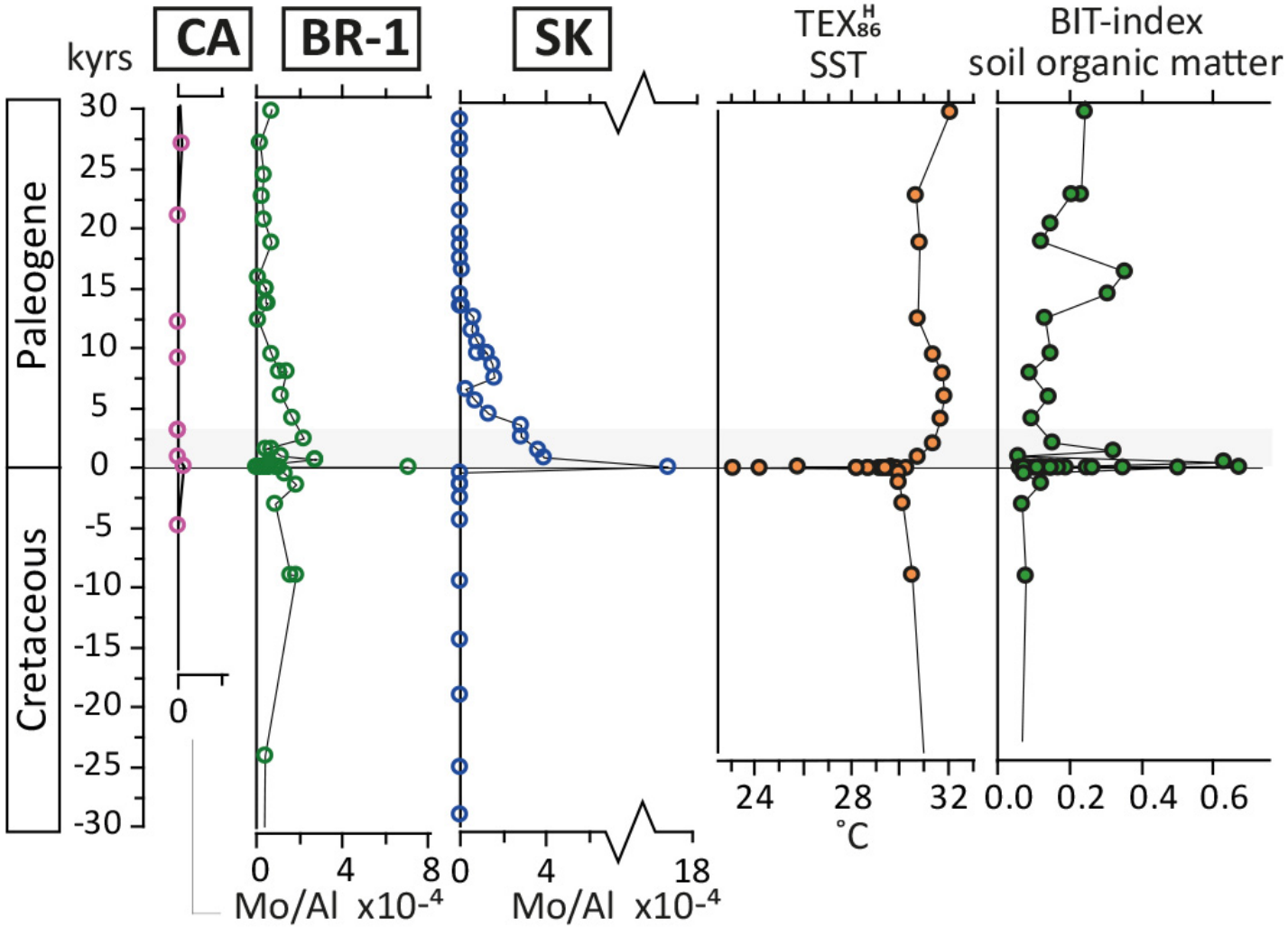
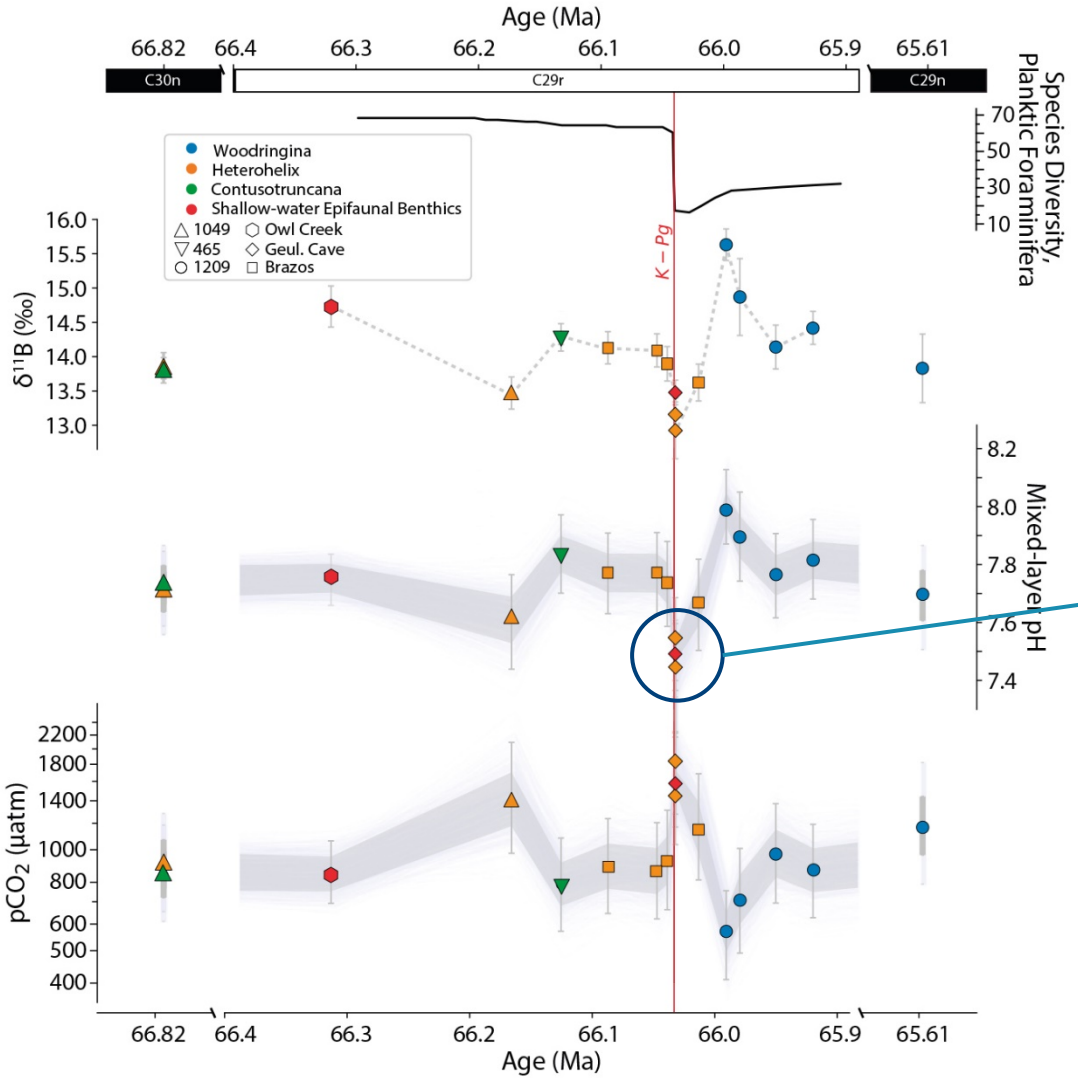
Opwarming na de inslag: kustzeeën verliezen zuurstof



- Hypoxia sterker & langer durend in ondiepe kustzeeën

Vellekoop *et al.*, 2018

Opwarming na de inslag: oceaanverzuring





Geulhemmerberg (Nederland)

Henehan *et al.*, 2019 (PNAS)

Samentvattend:

Chicxulub inslag resulteerde in:

- **bosbranden**
- **aardbevingen**
- **tsunami's**
- **korte "inslag winter"**
- **zure regen**
- **oceaanverzuring**
- **opwarming van de aarde,** geassocieerd met **hypoxia/anoxia op de zeebodem** in ondiepe kustzeeën

Vellekoop *et al.*, 2014, 2015, 2016, 2018, *en vele anderen*

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Wat waren de gevolgen voor de mariene fauna in de Belgische subtropische krijtzee?



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Hoe zag België er uit, 66.04 miljoen jaar geleden?



Grote delen van Europa bedekt door een warme ondiepe, subtropsiche zee

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Cretaceous Period

Eonothem/ Eon	Erathem/ Era	System/ Period	Series/ Epoch	Stage/ Age	millions of years ago
Phanerozoic	Mesozoic	Cretaceous	Upper	Maastrichtian	66.0
					72.1 ± 0.2
				Campanian	
					83.6 ± 0.2
				Santonian	86.3 ± 0.5
				Coniacian	89.8 ± 0.3
				Turonian	93.9
				Cenomanian	100.5
			Lower	Albian	
					~113.0
				Aptian	
					~125.0
				Barremian	~129.4
				Hauterivian	~132.9
				Valanginian	~139.8
				Berriasian	~145.0

Published with permission from the International Commission on Stratigraphy (ICS). International chronostratigraphic units, ranks, names, and formal status are approved by the ICS and ratified by the International Union of Geological Sciences (IUGS).

Source: 2012 International Stratigraphic Chart produced by the ICS.

KLEIN INTERMEZZO

“Maastrichtian”



1849: André Hubert Dumont

KU LEUVEN

Vernoemt naar de gesteentes tussen Luik en Maastricht





KU LEUVEN

type Maastrichtiaan



- ENCI groeve

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Hoe zag België er uit, 66.04 miljoen jaar geleden?





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Hoe zag België er uit, 66.04 miljoen jaar geleden?



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Kelmis (BE)



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Hoe zag België er uit, 66.04 miljoen jaar geleden?





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Hoe zag België er uit, 66.04 miljoen jaar geleden?







KU LEUVEN

Hoe zag België er uit, 66.04 miljoen jaar geleden?















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Hoe zag België er uit, 66.04 miljoen jaar geleden?



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Hoe zag België er uit, 66.04 miljoen jaar geleden?



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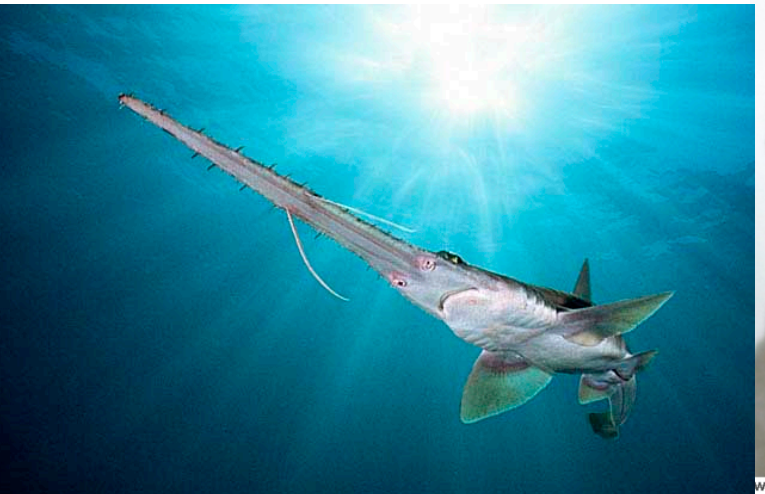



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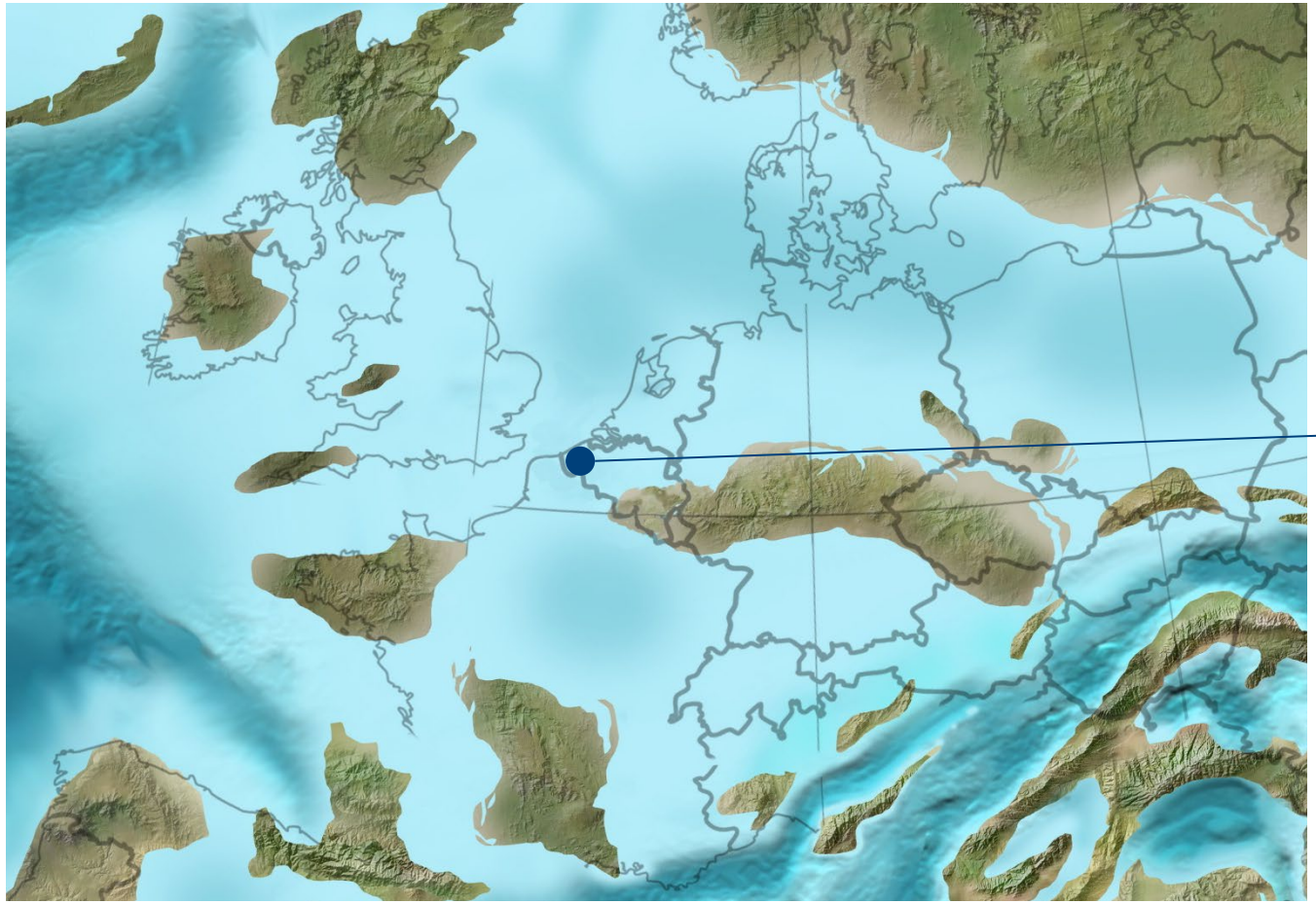
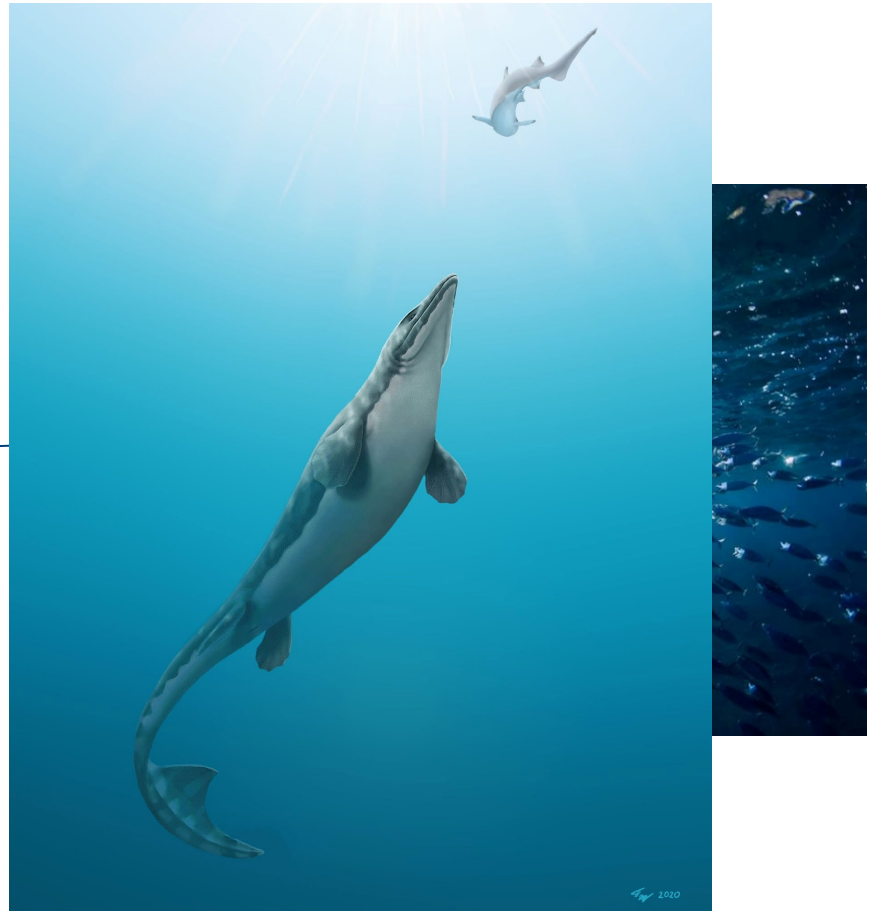
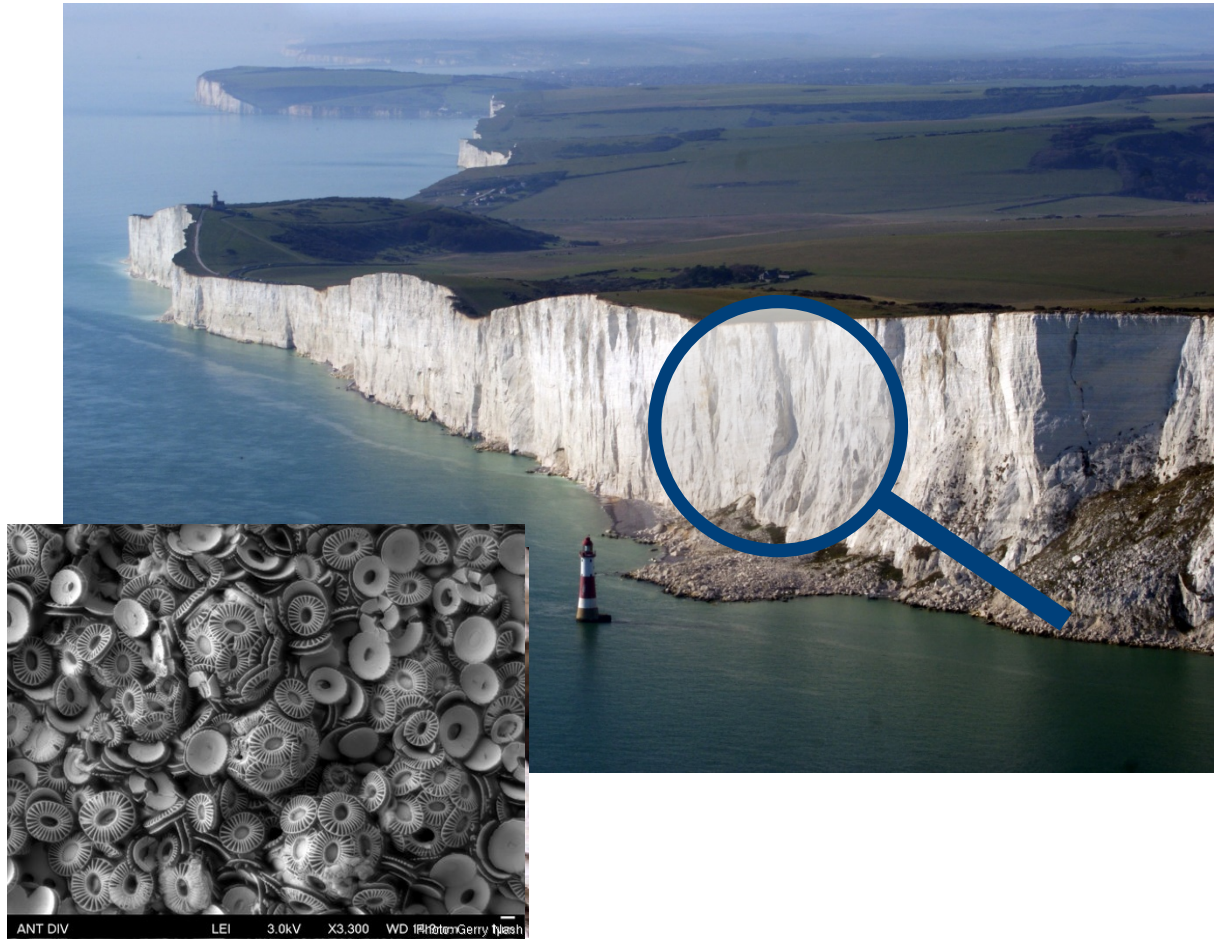
Hoe zag België er uit, 66.04 miljoen jaar geleden?





Hoe zag België er uit, 66.04 miljoen jaar geleden?





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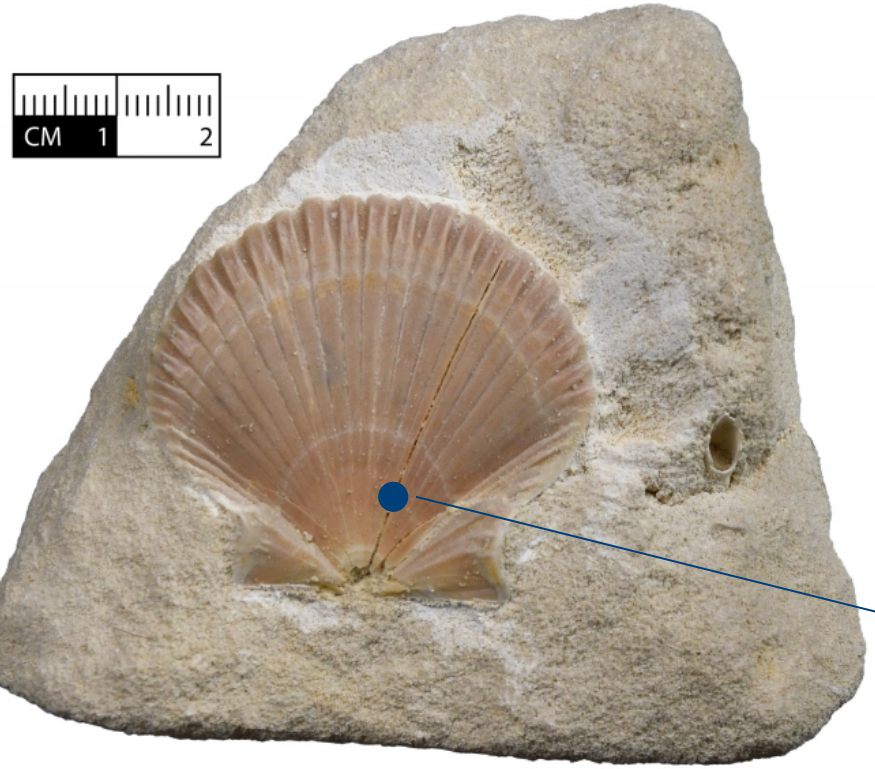
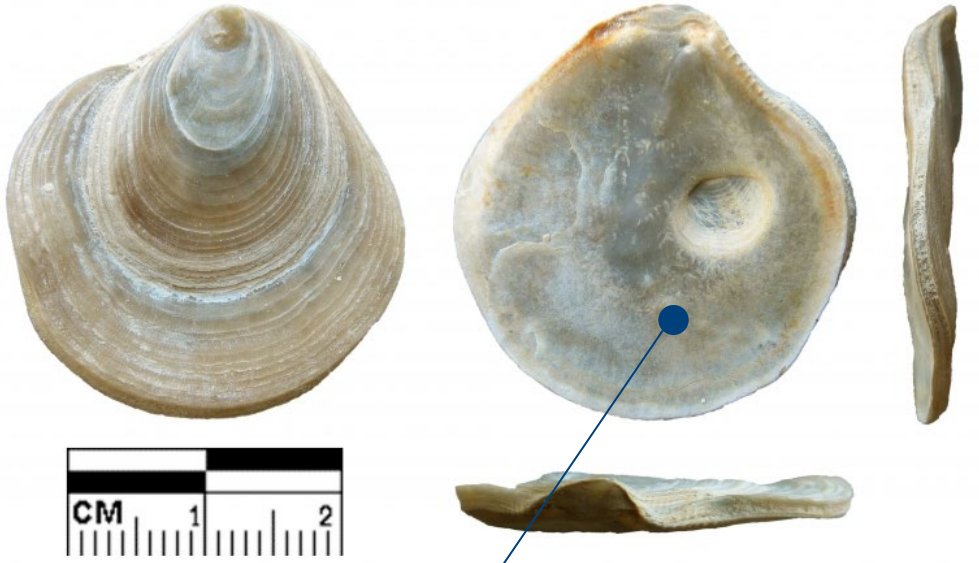
Hoe zag België er uit, 66.04 miljoen jaar geleden?

- **Het klimaat van België? => CO_2 concentraties ~800 ppm (2x huidig)**



www.fossiel.net © Johan Vellekoop



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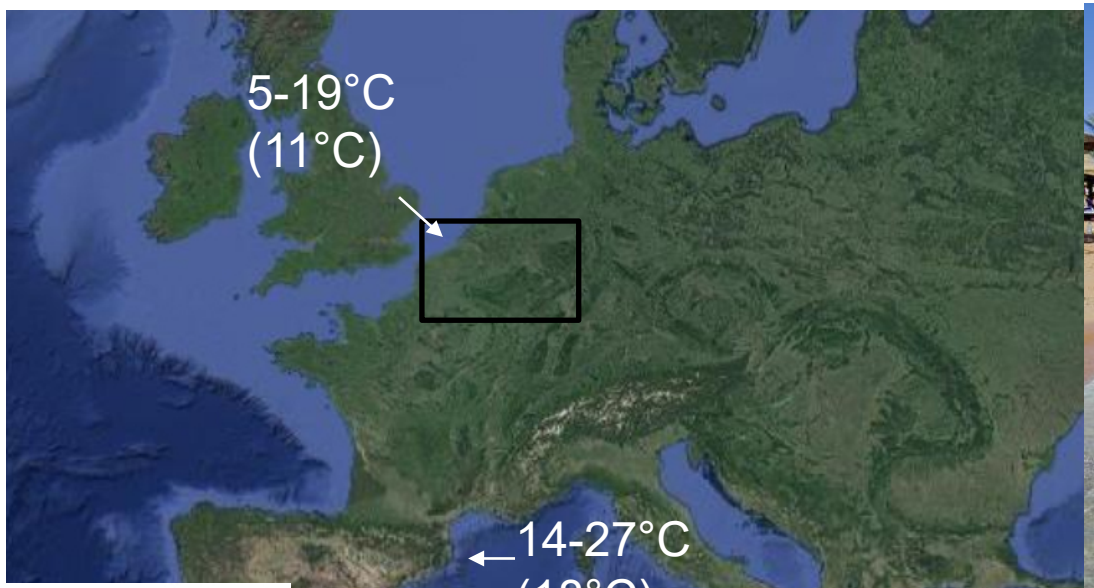
Clumped-isotopen temperatuur: ~22°C

O'Hora *et al.*, [in review]

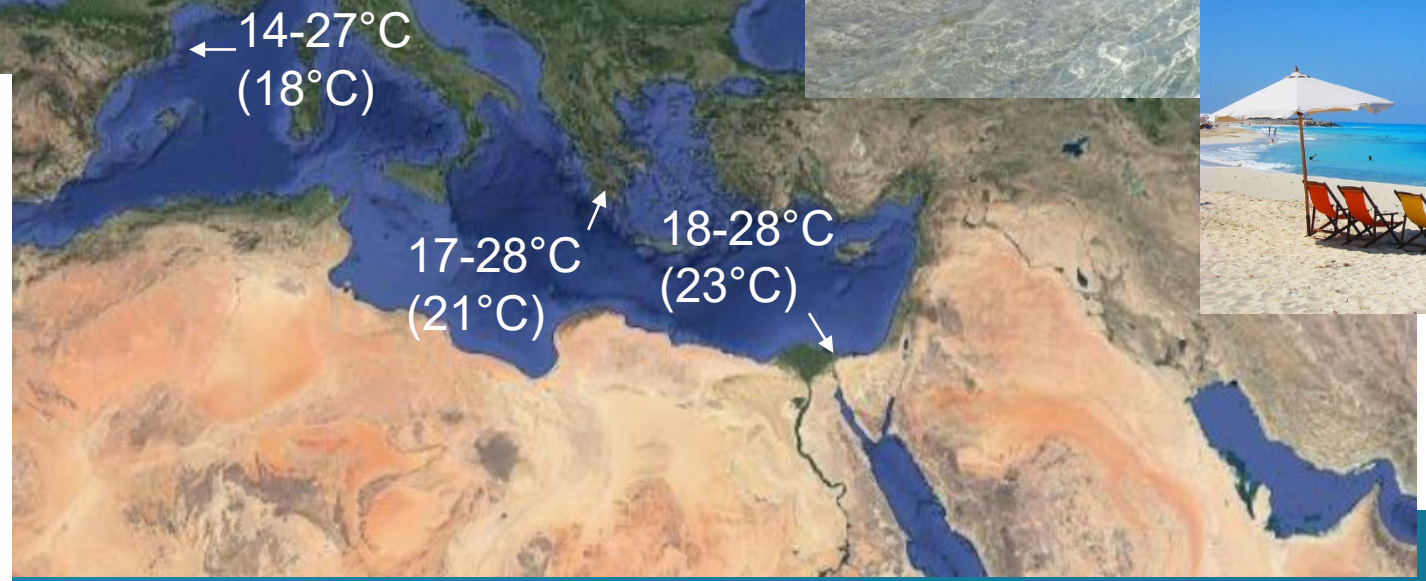
KU LEUVEN

Hoe zag België er uit, 66.04 miljoen jaar geleden?

België aan het einde van het Krijt: 22°C









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België aan het einde van het Krijt tijdperk

- **Een (sub) tropisch (zwem) paradijs……**





België aan het einde van het Krijt tijdperk

……waar ruw een einde aan kwam…

Wereldwijde catastrophes:

- **binnen 1 dag** (schokgolf, tsunami's etc.)
- **weken tot decennia** (zure regen, "inslag winter", mega orkanen)
- **eeuwen tot millennia** (klimaatverandering, etc.)
- **miljoenen jaren** (biologisch herstel, C-cyclus respons…)

De meteorietinslag: wereldwijde catastrophes

- **België ontkomt er niet aan…**

➢ **binnen 1 dag** (schokgolf, bosbranden, tsunami's etc.)



Vermoedelijk geen bosbranden

?



De meteorietinslag: wereldwijde catastrophes

- **België ontkomt er niet aan…**

➢ **binnen 1 dag** (schokgolf, bosbranden, tsunami's etc.)





Maar wel een tsunami

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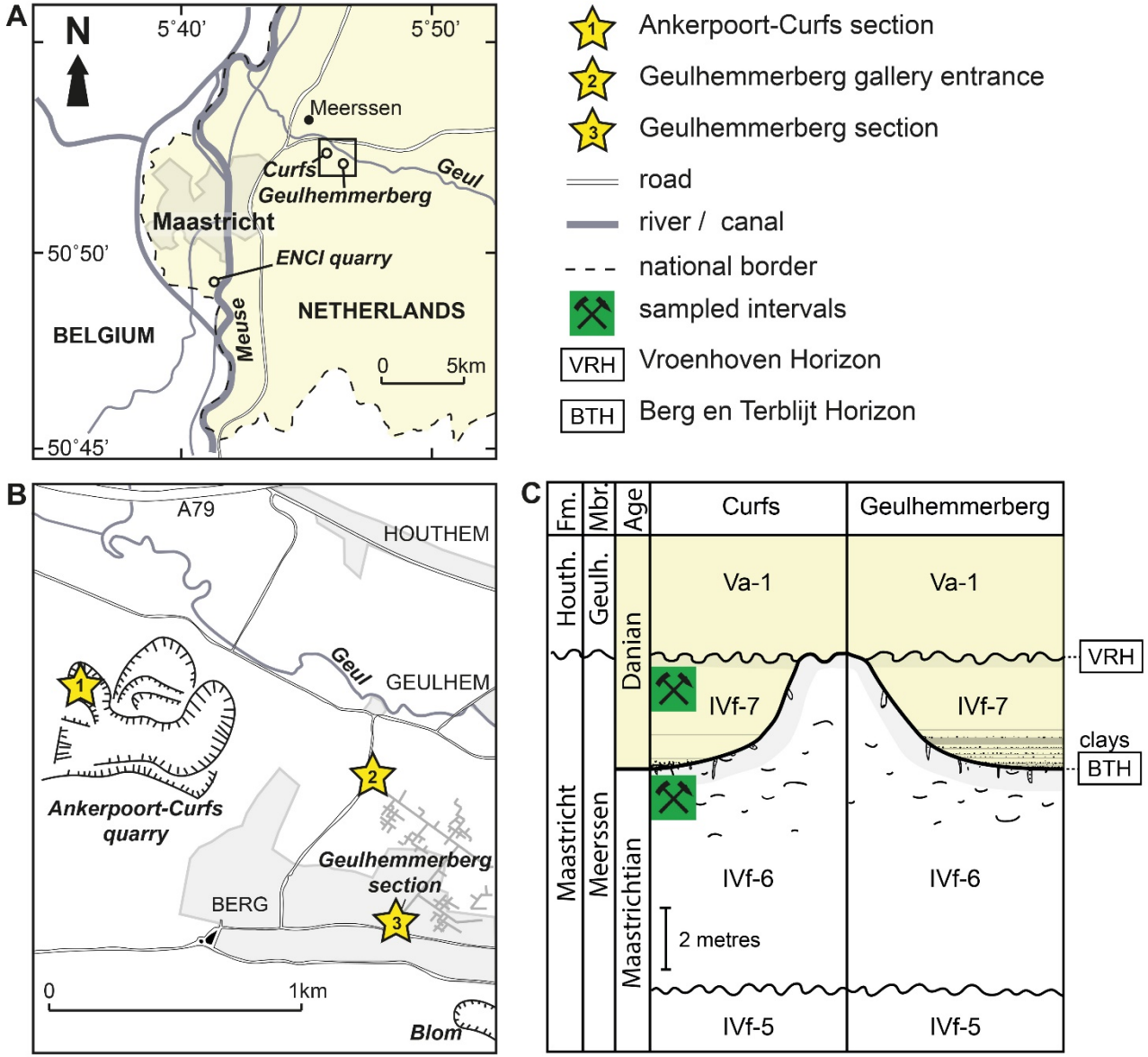

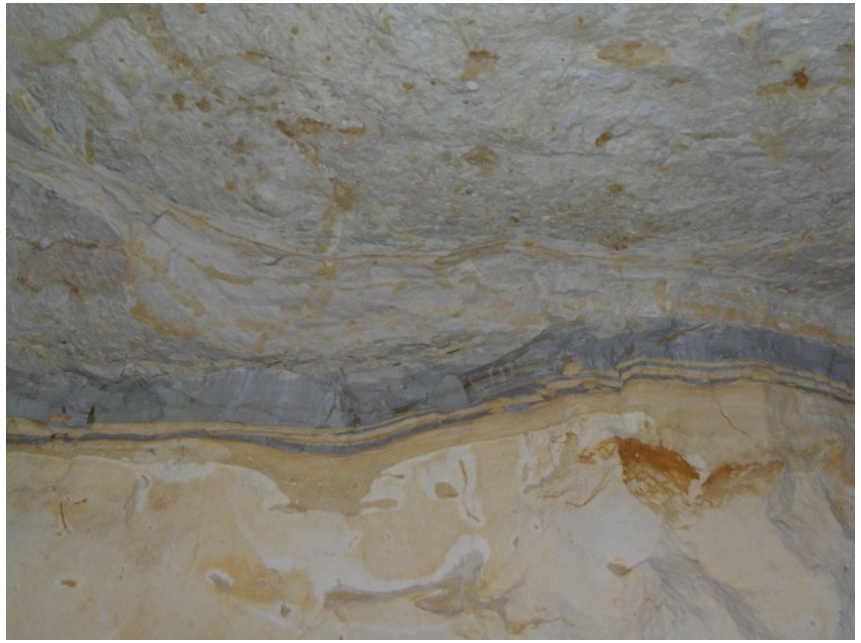

Geulhemmerberg (Nederland)

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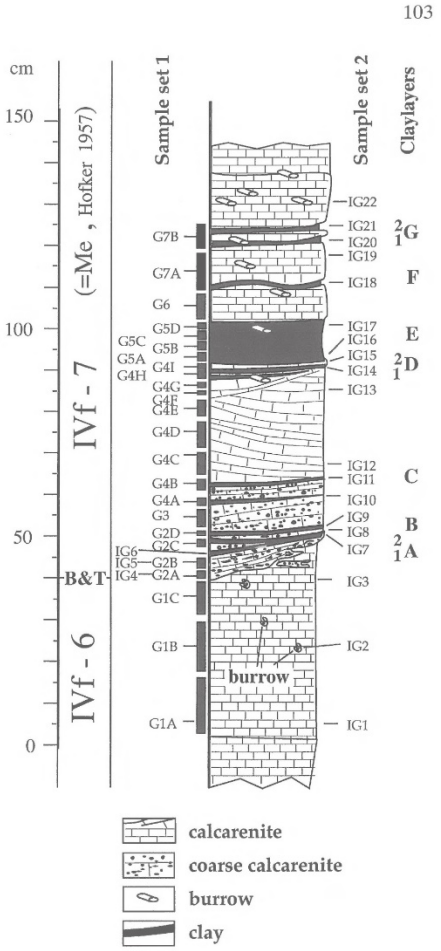
Vellekoop et al. 2020

De meteorietinslag: catastrophes in België



Geulhemmerberg



Serie tsunami's of seiches verstoort de zeebodem in ondiepe delen

Smit & Brinkhuis, 1996 [NJG]

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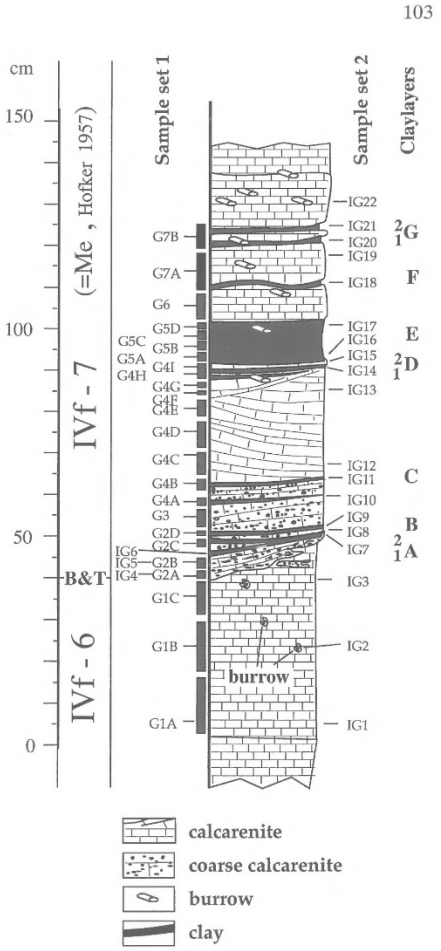
De meteorietinslag: catastrophes in België



Na de tsunami in Sumatra (2004)



Serie tsunami's of seiches verstoort de zeebodem in ondiepe delen

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De meteorietinslag: catastrophes in België

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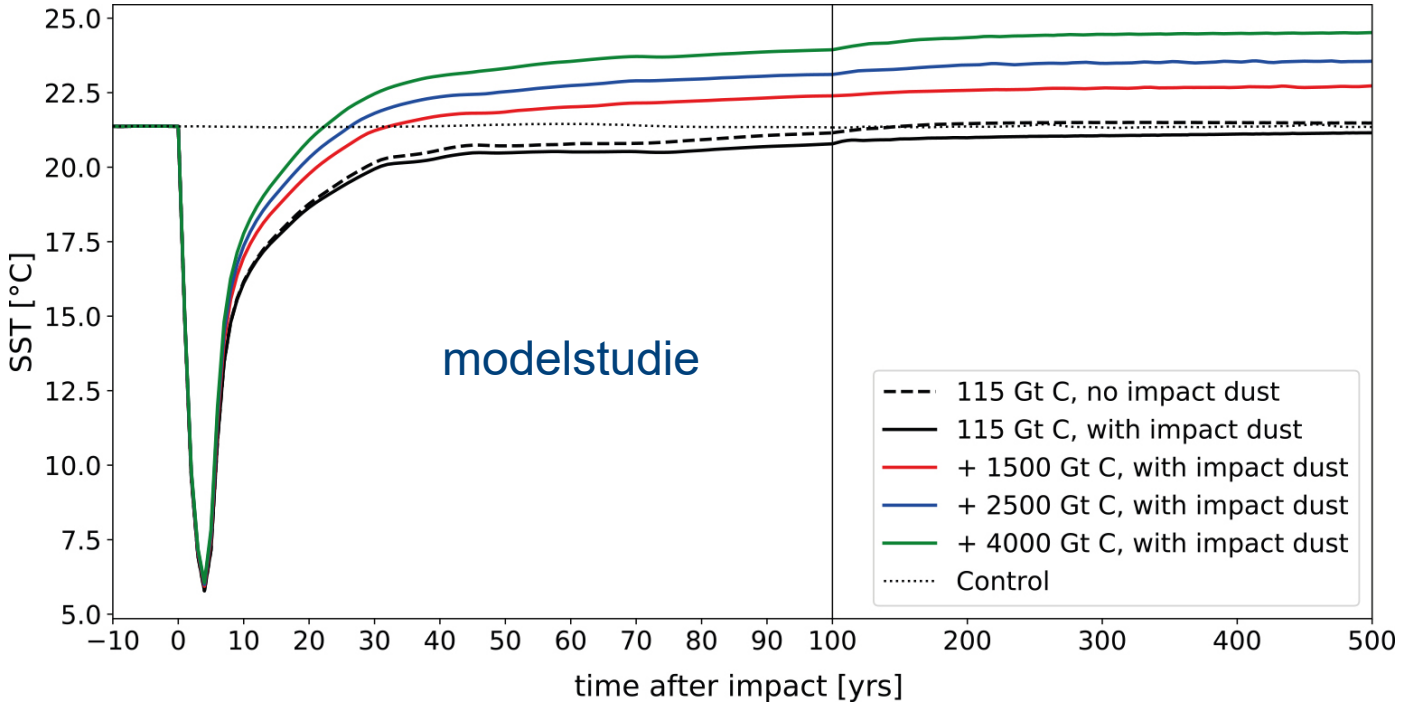
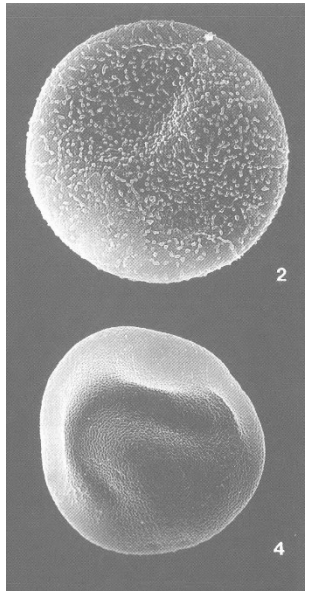


Inslagwinter: 1-10 jaar van afkoeling en schemering

Brugger et al., 2021

België:
piek aan mossen
(bryophyten)







Brinkhuis & Smit, 1996

De meteorietinslag: catastrophes in België

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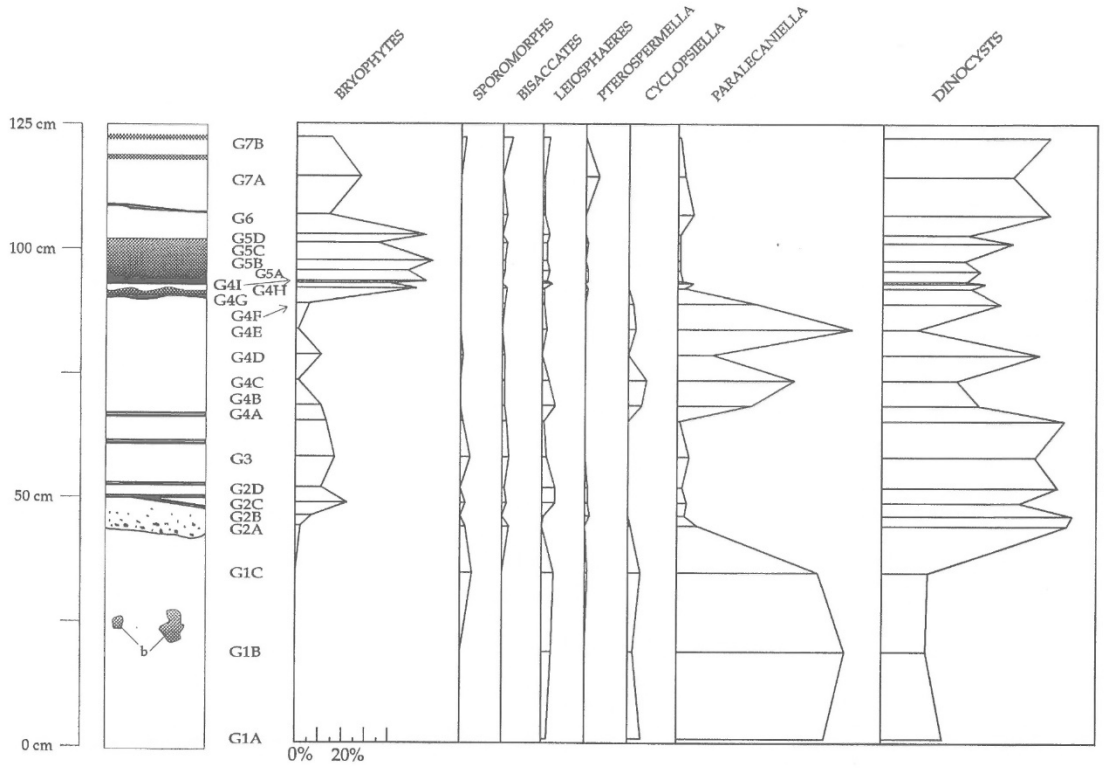
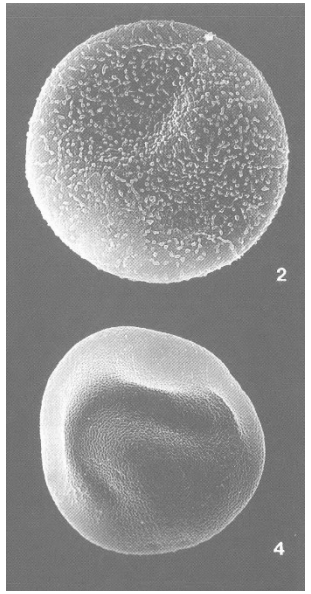


Inslagwinter: 1-10 jaar van afkoeling en schemering



België:
piek aan mossen
(bryophyten)





Brinkhuis & Smit, 1996

De meteorietinslag: catastrophes in België

- **België ontkomt er niet aan…**
- ➢ **eeuwen tot millennia** (klimaatverandering, etc.)



?



Gevolgen onzeker….

Brinkhuis & Smit, 1996

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De meteorietinslag: de slachtoffers

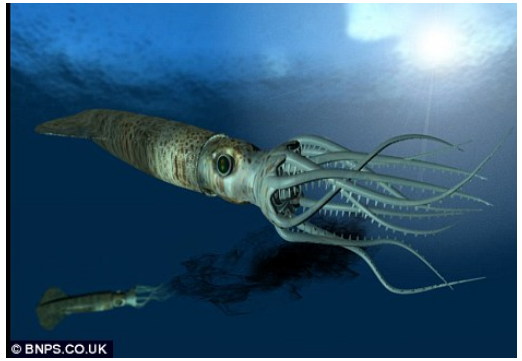




Gewervelden: reptielen







Cephalopoden:
ammonieten en belemnieten



koralen

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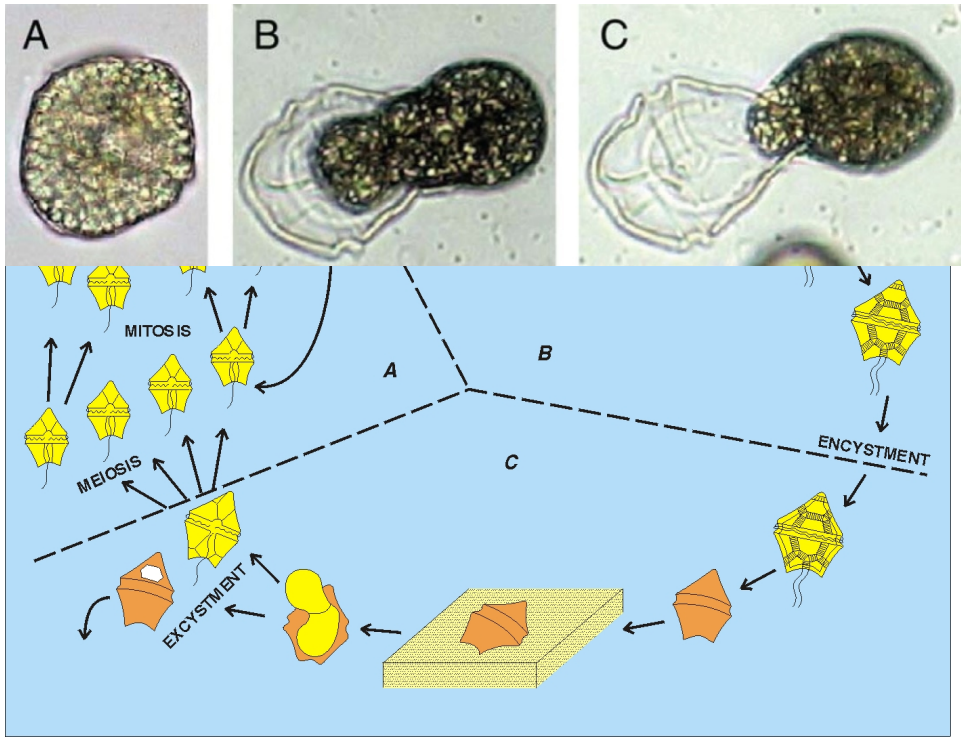
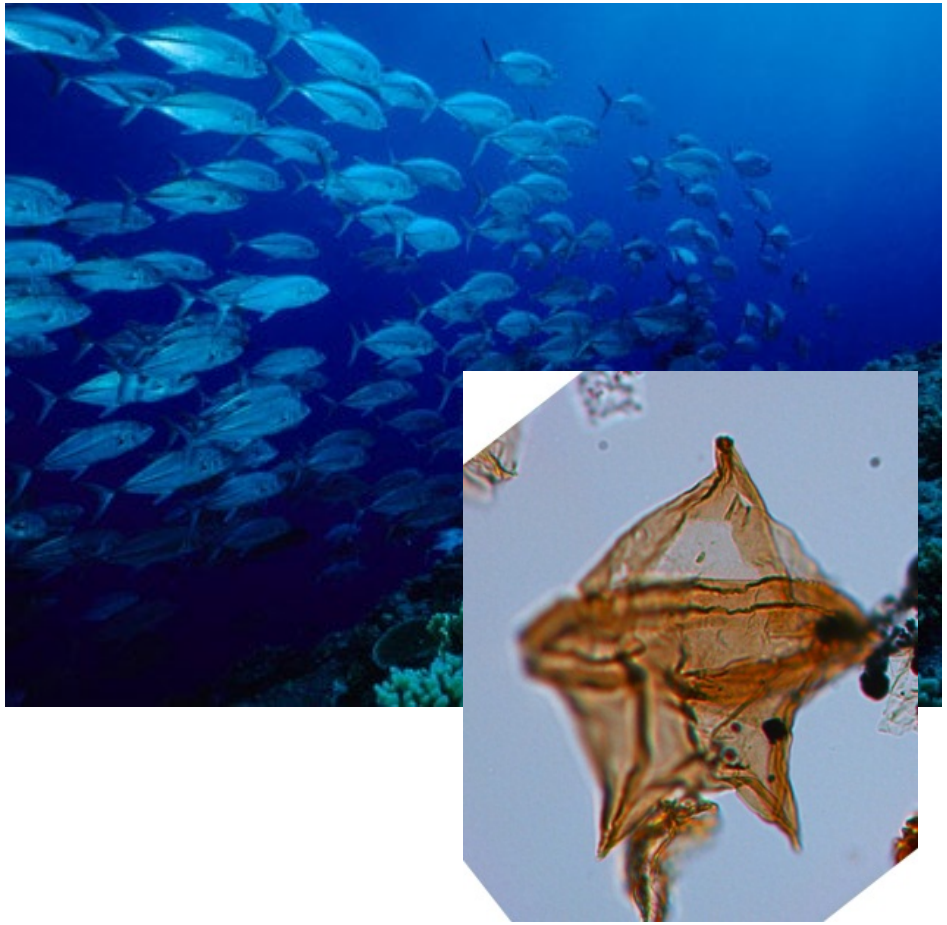
De meteorietinslag: de overlevers

- **Zij die geluk hebben?**



e.g. Ribeiro *et al.*, 2011



generalistsen en groepen die een vorm van incumbentie/kiemrust hebben

Brinkhuis & Smit, 1996; Vellekoop et al., 2020, *en vele anderen*

Wie zijn de winnaars, wie de verliezers?

i.e.: Hoe overleef ik een asteroïde inslag?

- **Formaat**
  - **Klein is beter dan groot!**
- **Levenstrategie**
  - **Cyst-bouwend, dormant stage, zaden**
  - **generalisten over specialisten**
  - **deposit feeders over filter feeders**
- **Voor plankton:**
  - **Skelet zonder kalk is een pré!**

- **<u>en vooral heel veel geluk!</u>**



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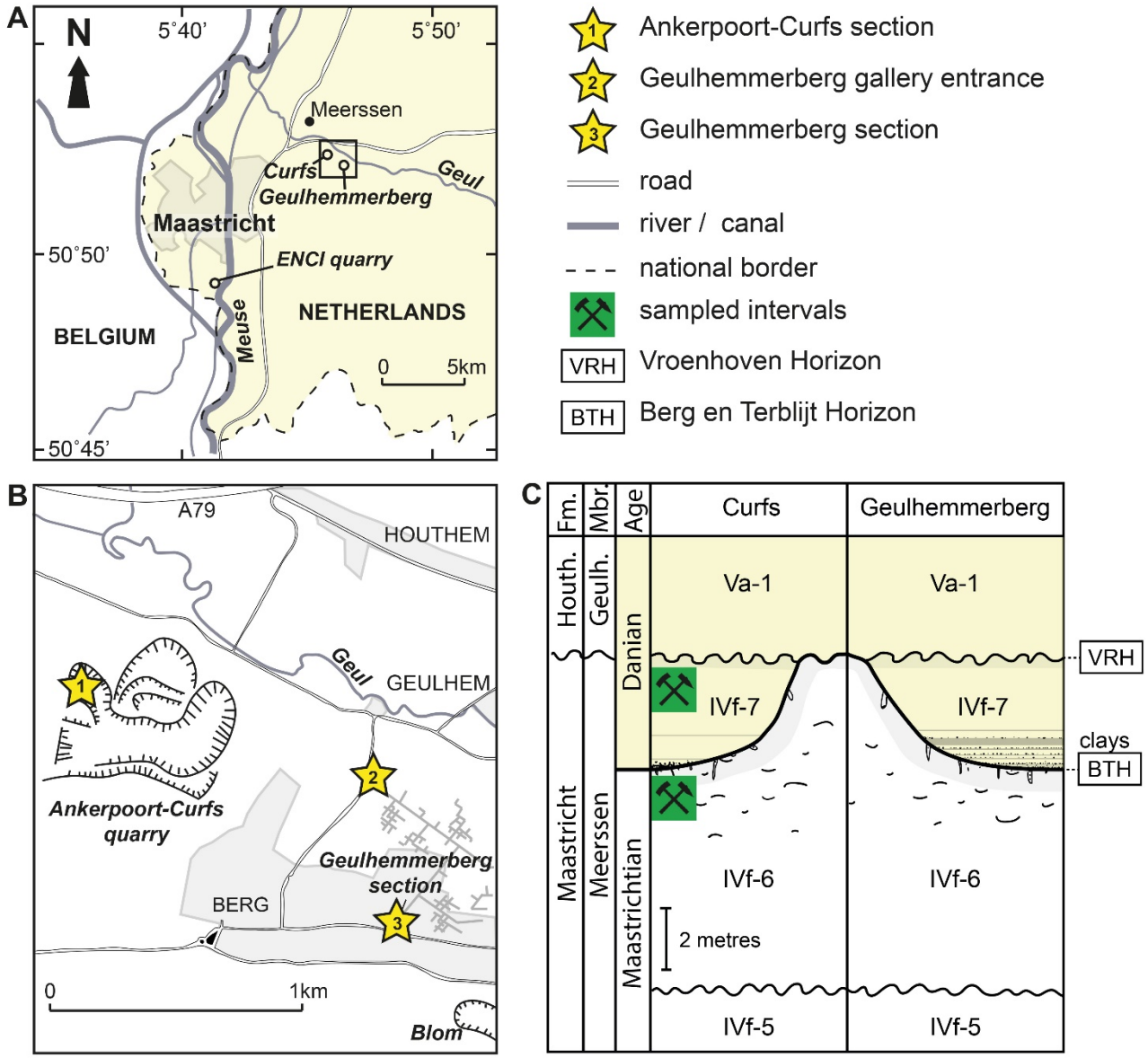
Andere groepen?





Ankerpoort-Curfs groeve (Nederland)

Vellekoop et al. 2020

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(voormalige) Curfs-Ankerpoort groeve



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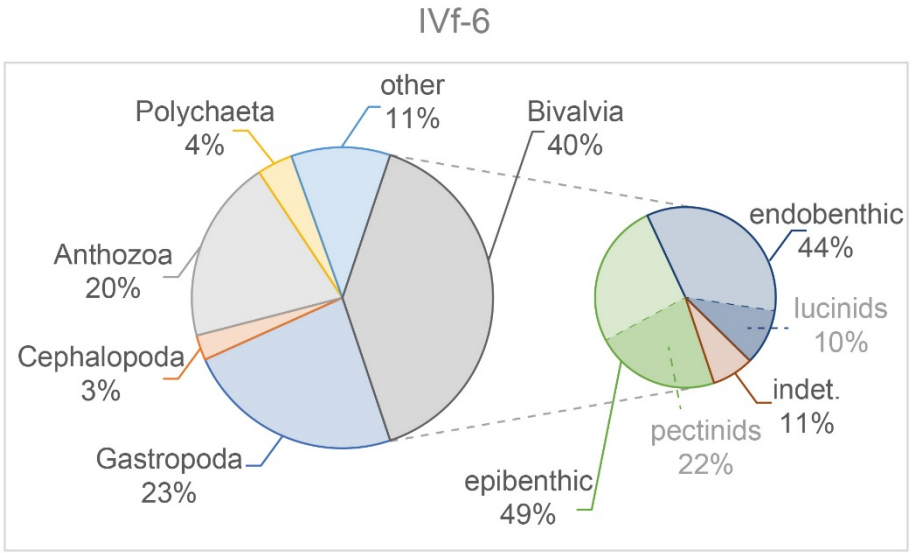
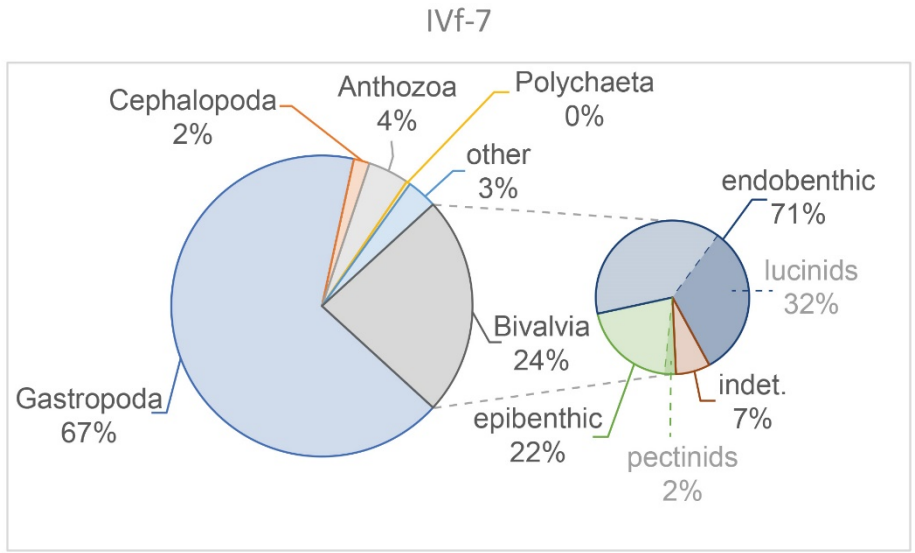
Macro-invertebraten



Voor de inslag



Na de inslag

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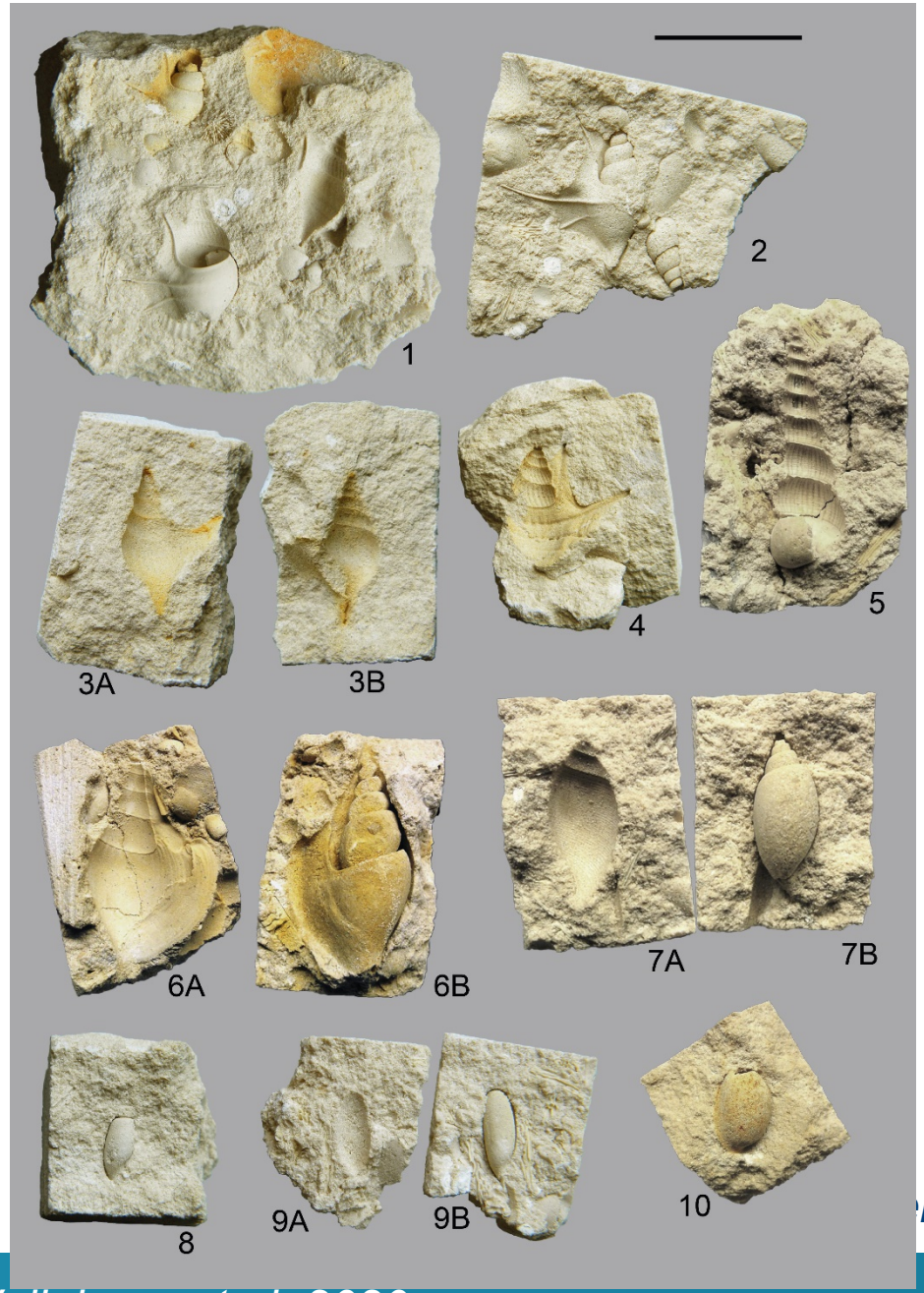
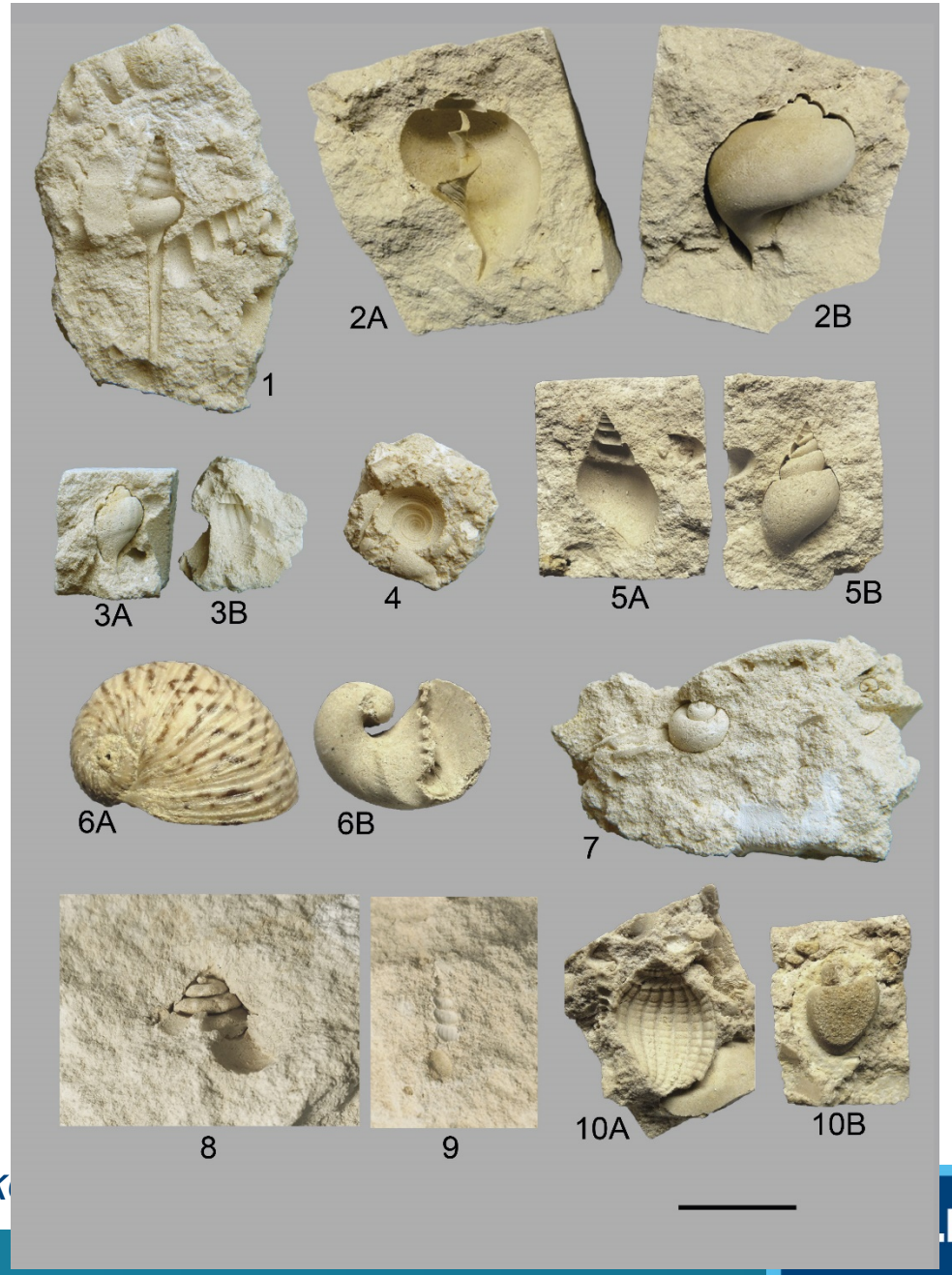
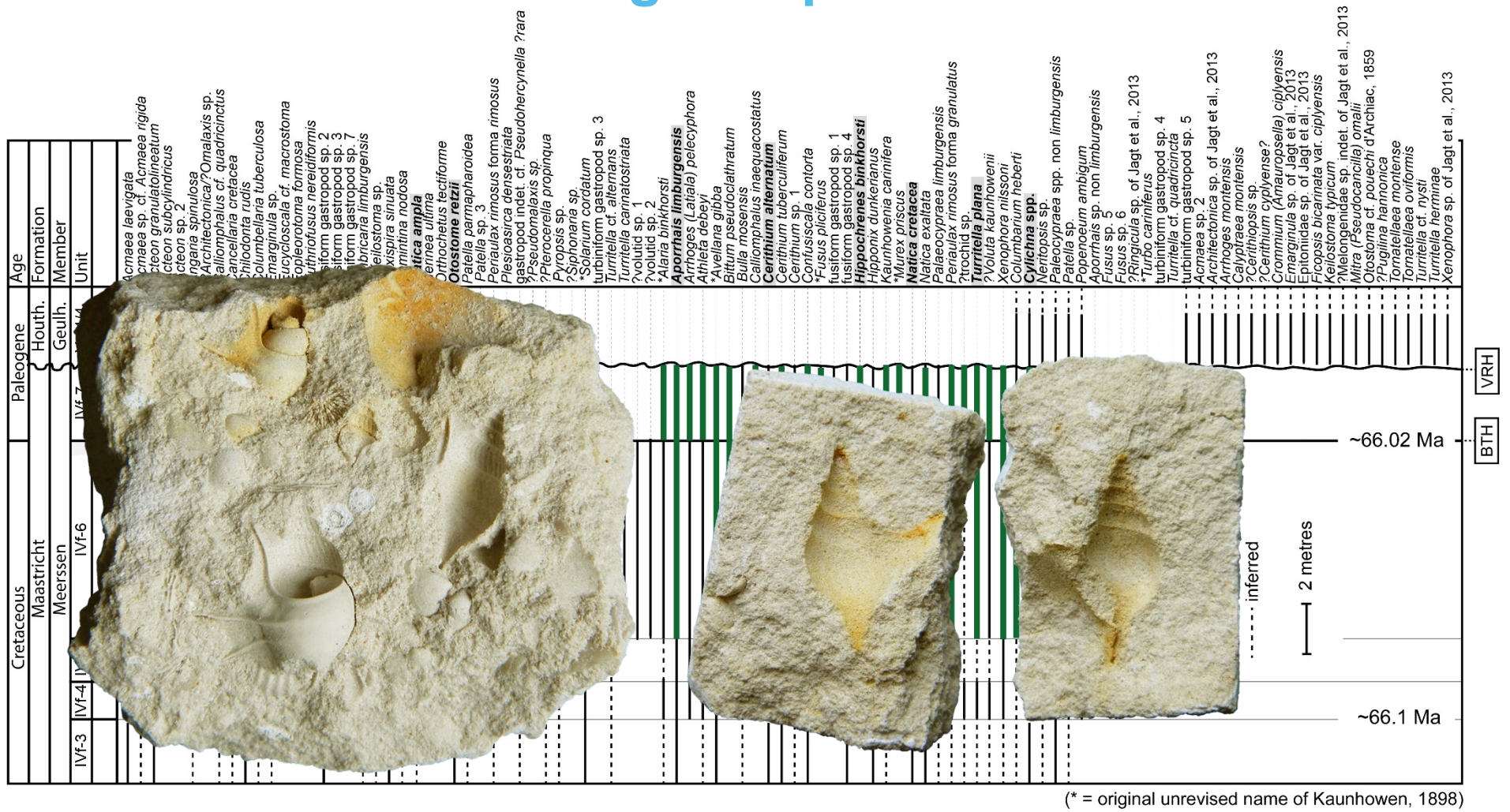
Vellekoop et al. 2020





Vellekoop et al. 2020

gastropoda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Houth.
Geulh.
Meerssen
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IVf-4
IVf-6
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Member
Unit
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Acmaea sp. cf. Acmaea rigida
Acteon granulatolineatum
Acteon subcylindricus
Acteon sp. 2
Angaria spinulosa
Architectonica/?Omalaxis sp.
Calliomphalus cf. quadricinctus
Cancellaria cretacea
Chilodonta rudis
Columbellaria tuberculosa
Emarginula sp.
Eucycloscala cf. macrostoma
Ficopleorotoma formosa
Fusiform gastropod sp. 2
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De meteorietinslag en zijn gevolgen voor de mariene fauna in de Belgische subtropische krijtzee.

- Ecosysteem veranderingen over de K-Pg grens zijn beperkt, in de Belgische subtropische krijtzee
- Een aantal groepen (vertebraten, cephalopoden, koralen etc) verdwijnen, andere groepen overleven (bivalven, gastropoden, dinoflagellaten etc).
- De fauna van het vroege Paleoceen lijkt nog veel op die van de Krijtzee
- Overlevende soorten maakten herkolonisatie mogelijk, waardoor het ecosystem tijdelijk kon herstellen.
- Daarna graduale vervanging door nieuwe Paleocene soorten

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Bedankt voor uw aandacht!



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