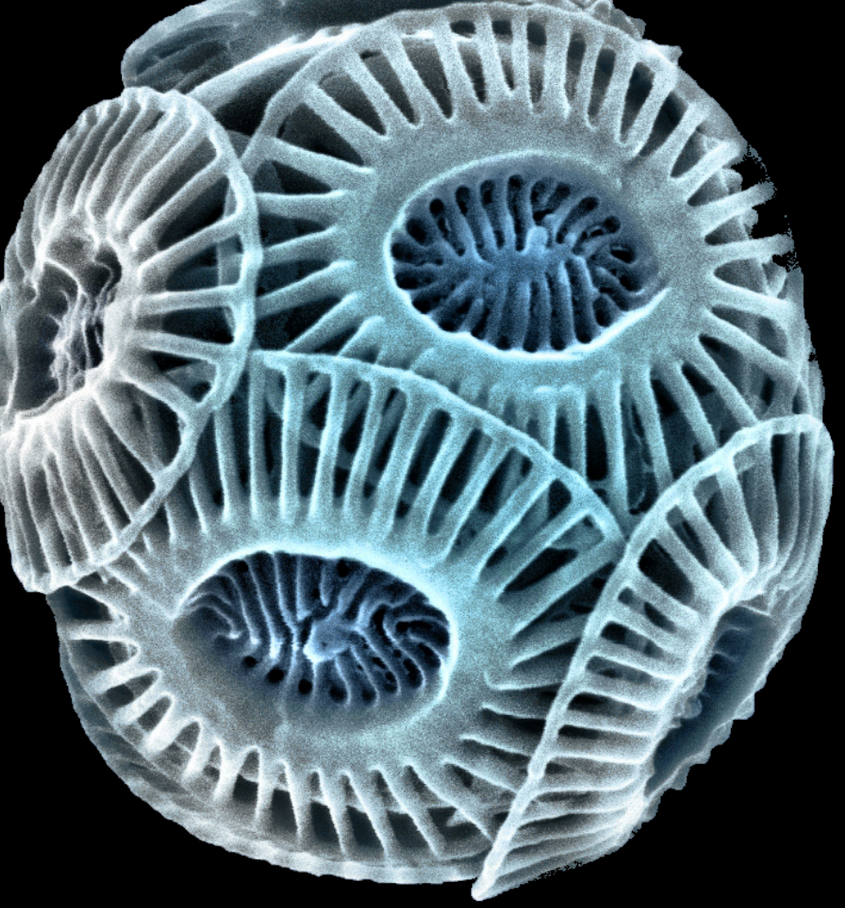


Automatic calcareous nannofossil biostratigraphy using the latest version of SYRACO

Luc Beaufort, Yves GALLY, Thibault de Garidel-Thoron, Ross Marchant, Martin Tetard
CEREGE
Aix-en-Provence
France

SYRACO
SYstème de Reconnaissance Automatique de COccolithes

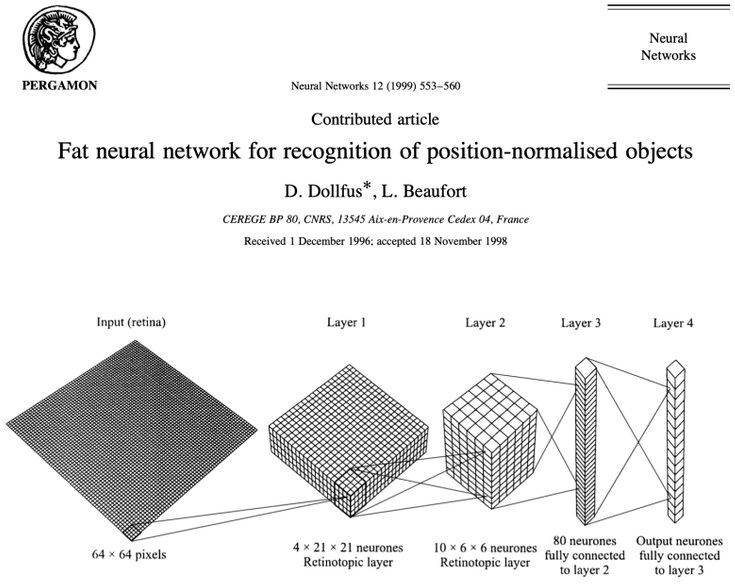
- Method based on CNN and automated microscopy that we started to developed in the 90's

- Both CNN, and microscopy have evolved since the beginning and we constantly adapted new method to SYRACO

- SYRACO is used routinely at CEREGE and in 7 teams around the world

Neural networks

1999



PERGAMON

Neural Networks

Neural Networks 12 (1999) 553–560

Contributed article

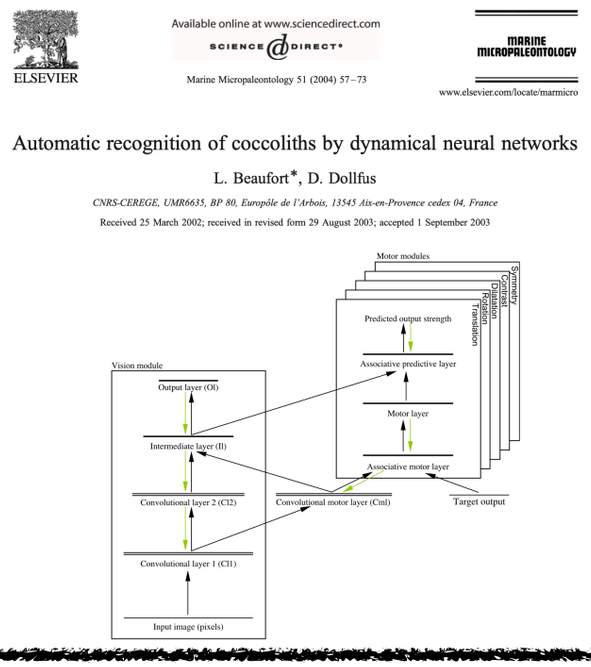
Fat neural network for recognition of position-normalised objects

D. Dollfus*, L. Beaufort

CEREGE BP 80, CNRS, 13545 Aix-en-Provence Cedex 04, France

Received 1 December 1996; accepted 18 November 1998

2004



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Marine Micropaleontology 51 (2004) 57–73

MARINE MICROPALEONTOLOGY

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Automatic recognition of coccoliths by dynamical neural networks

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Received 25 March 2002; received in revised form 29 August 2003; accepted 1 September 2003

2020

Particle trieur,
Marchand et al., subm.

ResNet (*He et al., 2015*):
basic cyclic network with
16 filters and the addition of
residual connections

Evolution of the recognition accuracy (%) on key nannofossil species

	CNN on FFT	CNN on images	Dynamical CNN	ResNet (ParticleTrieur)
	SYRACO I (1996)	SYRACO II (1998)	SYRACO III (2004)	SYRACO V (2020)
C.leptoporus	40	96	96	100
U.tenuis	49	89	95	87
U.sibogae	75	80	87	100
E.huxleyi	83	99	97	100
G.caribbeanica	26	82	86	100
G.oceano		84		87
S. pulchra	40	80	80	100
***Syracosphaera* spp**	41	87	87	100
Pontosphaera spp	42	80		91
H.carteri	10	96	96	100
Rhabdoliths sp	90	89	88	100
Scapholithes			98	100
F. profunda	23	83	86	96
Average	47	87	91	97

Evolution of methods

Year	Lens resolution	Camera	Pixel light	Polarisation	Focus	Slide preparation method	Patern recognition
1996	50X	0.5 Mpixel	0.3 µm	Linear	Auto	Smear slides	CNN
2004	50X	0.5 Mpixel	0.3 µm	Linear	Auto	Smear slides	Dyn CNN + hierarchy
2012	100X	4 Mpixel	0.062 µm	Linear	Auto	Smear slides	Dyn CNN + hierarchy
2014	100X	4 Mpixel	0.062 µm	Rotative / circular	Auto	Random settling	Dyn CNN + Random Forest
2020	100X	4 Mpixel	0.059 µm	**Bidirectional Circular**	**Multi-focus**	Filtrated Radom settling	ResNet + size

***(breakthrough technological development)**

Details of current method

Microscope : Leica DM6000, Lens 100x 1.47 oel

Chroma Filters : monochrom 562 nm, 2 x Circular Pol +45°, Circular Pol -45°

Camera : Hamamatsu ORCA Flash v 4.1

Focus : Multi focus with 10 images grabbed at every 0.5 µm Z levels

Bidirectional circular polarization : 2 images grabbed and combined to get constant and standardized brightness *(Beaufort et al., Biogeosc. Disc., 2020)*

Batch of 16 samples/ microscope

2 batchs per day with 150 filed of view / sample => ~2000 cocco / sample

=> 32 samples a day /microscope

Confusion matrix for a Pleistocene core MD97-2125 (Tropical south Pacific)

Same species

Similar morphologies / same families

Problems (e.g. invasion, escape between different group or worse with non-coccoliths)

	Classe	Cle	Cla	Ut	Usi	Eh	Ge	Gc	Go	Pla	Ret	Sp	Syr	Po	Hc	Rh	Ba	Dis	Sc	Flo	oth	Th	Eg	Fra	Pel	Ag	Zer	Zer	ec
Cocco	C.leptoporus	100																											
	C. leptoporus asy	50	50																										
	U. tenuis		12	75	12																								
	U.sibogae				100																								
Noelarha	E.huxleyi					81	4				15																		
	G.ericso						79	18	3																				
	G.carib.						2	98																					
	G.oceano						3	9	81	3	3																		
	P.lacunosa									97	3																		
	Reticulo sp							5		5	85		5																
Cribri	S. pulchra											100																	
	Syraco. spp										38		50	12															
	Pontosphaera											9		91															
	Hcarteri														100														
	Rhabdo															100													
	Base Rhabdo															33	67												
	Discosphaera																	100											
	Scapholiths																		100										
	Florisphaera																			96							4		
	Other (rare cocco)																				100								
Non coccoliths	Thoraco (Dinoflag.)																					100							
	Eguille (needles)															8							92						
	Fragment			5																				89			5		
	Pelotte (pelet)																								100				
	Agregat																									91	9		
	Zero1 (dark)																			17				13			65	4	
	Zero2 (bright)																										20	80	
	Ecaille (scale)																												100

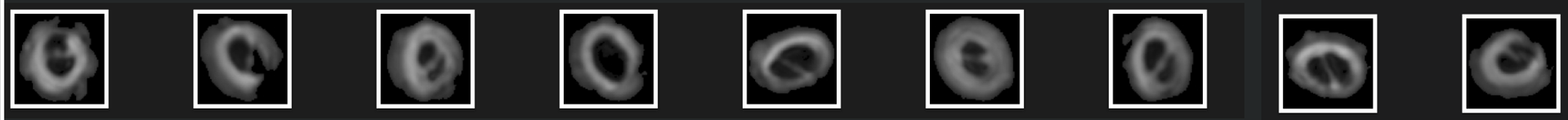
Work in progress : Based on a training set composed of 200 specimens per class. The errors made when applying on few samples are fed back in a new training set with a goal of 400 specimens per class.

MD97-2125 / 700 cm - 210 kyr BP => few *E.huxleyi* and no *P.lacunosa*

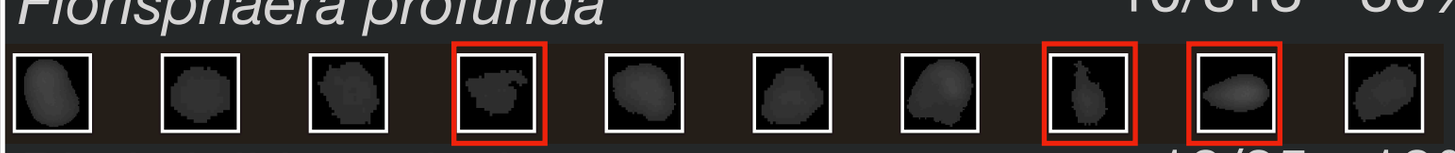
Gephyrocapsa ericsonii 10/499

Emiliania huxleyi 10/13

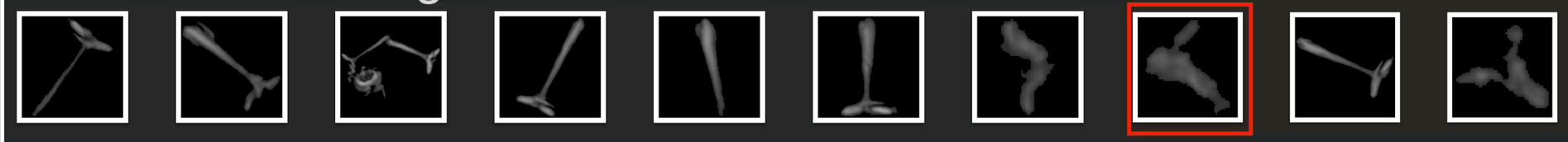
Gephyrocapsa oceanica 10/93



Florisphaera profunda 10/813 - 30% False positives



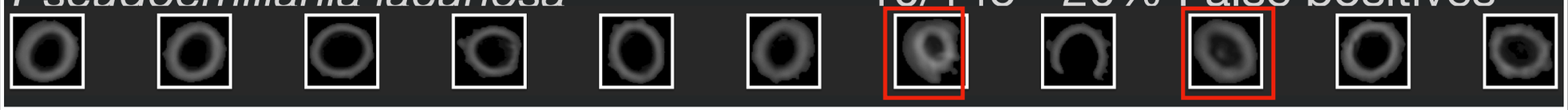
Rhabdolithus clavigera 10/35 - 10% False positives



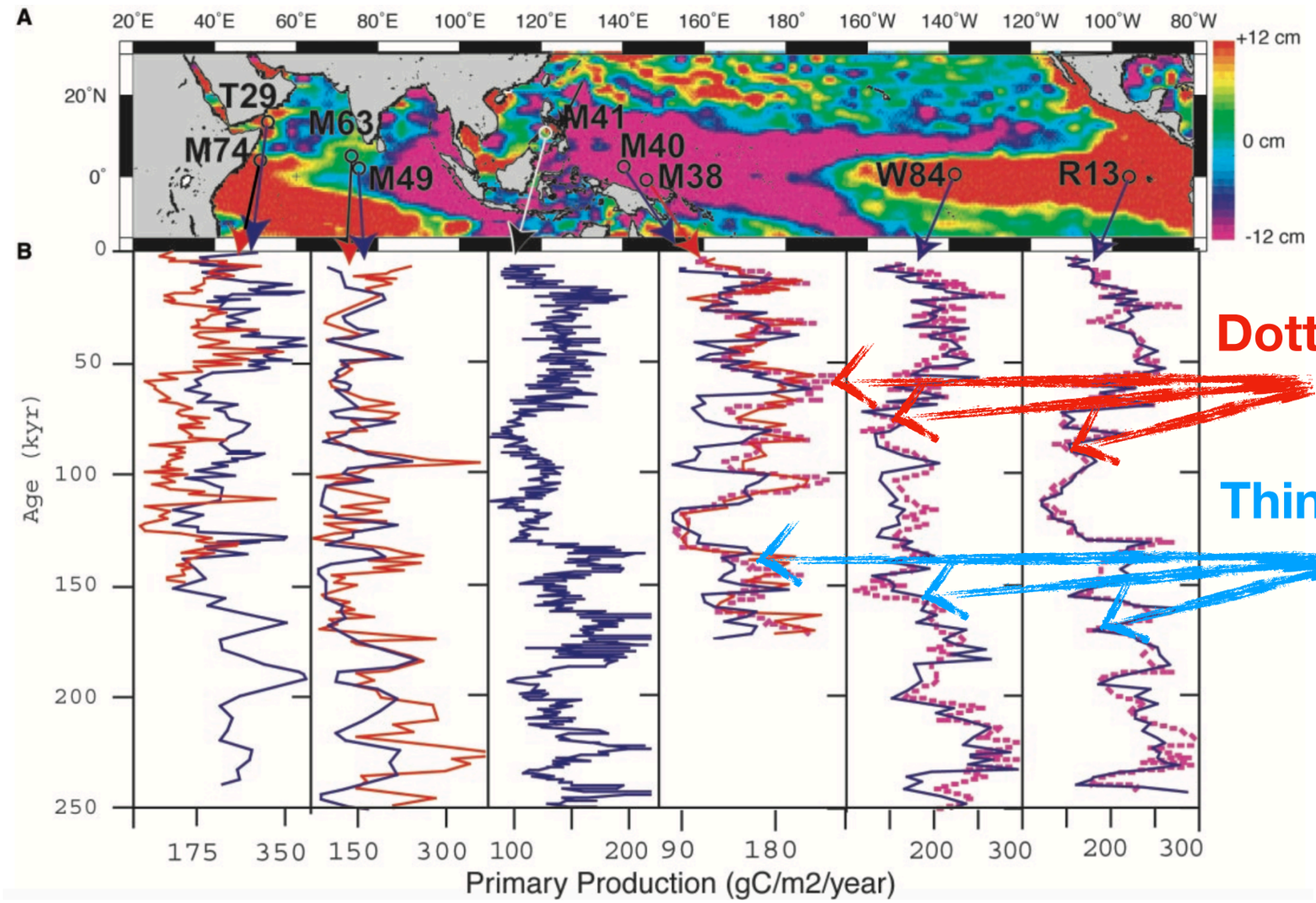
Pseudoemiliania lacunosa 10/54 - 100% False positives

MD97-2125 / 2700 cm - 620 kyr BP => Presence of *P.lacunosa*

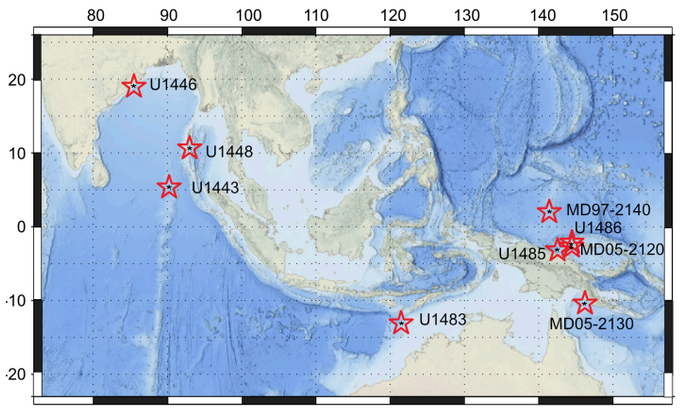
Pseudoemiliania lacunosa 10/145 - 20% False positives



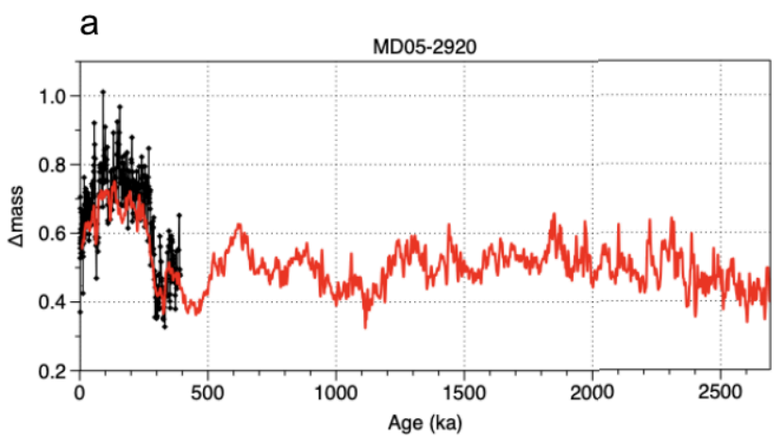
First publication with CNN for microfossil recognition in 2001

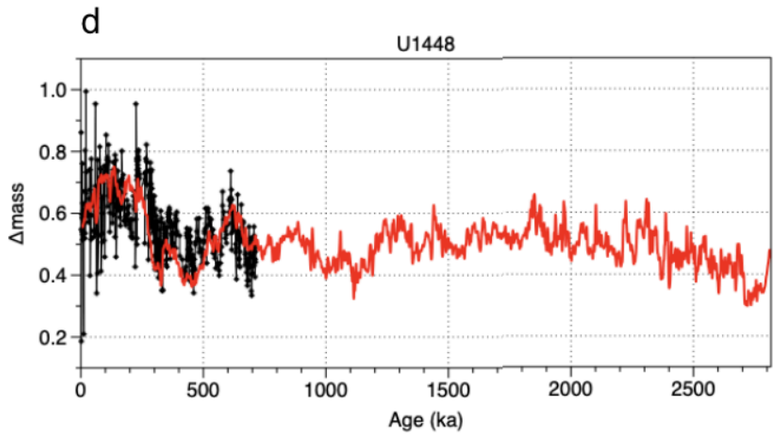


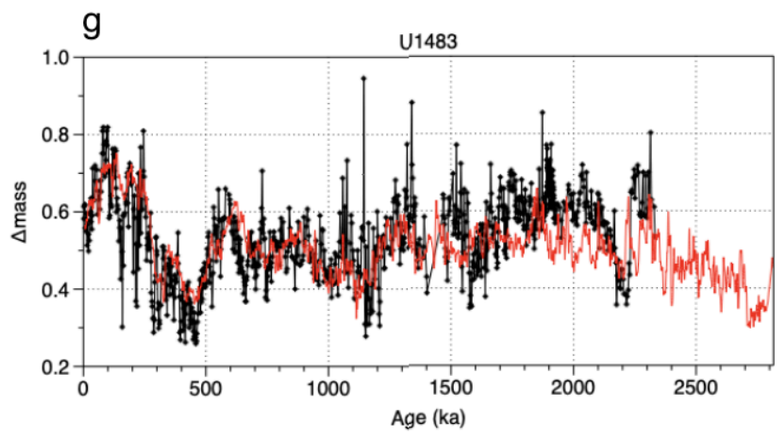
Beaufort, de Garidel-Thoron, Pisias & Mix, *Science*, 2001

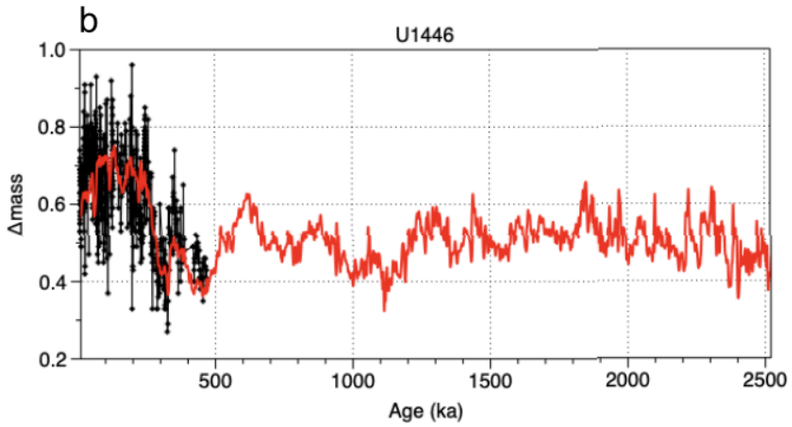


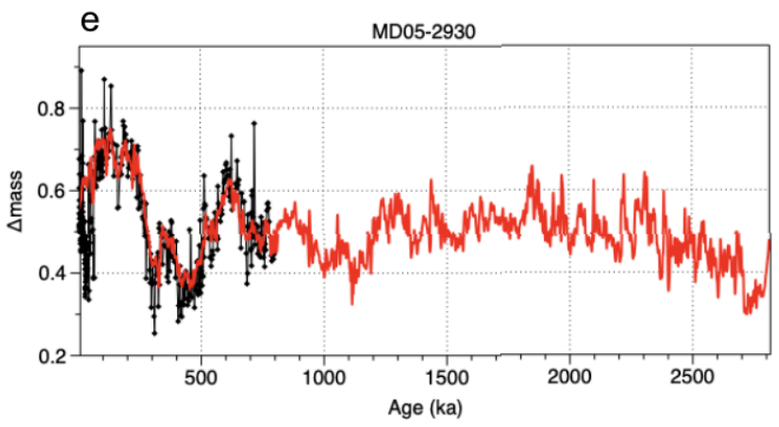
Δmass is the difference of the average mass of two groups of Gephyrocapsa. It traces the morphological evolution of the group. It can be easily measured with SYRACO with an excellent accuracy. It is global and therefore can be use as a quantitive stratigraphy.
Red : Stack. Black: individual records (see map)
(Beaufort et al., submitted)

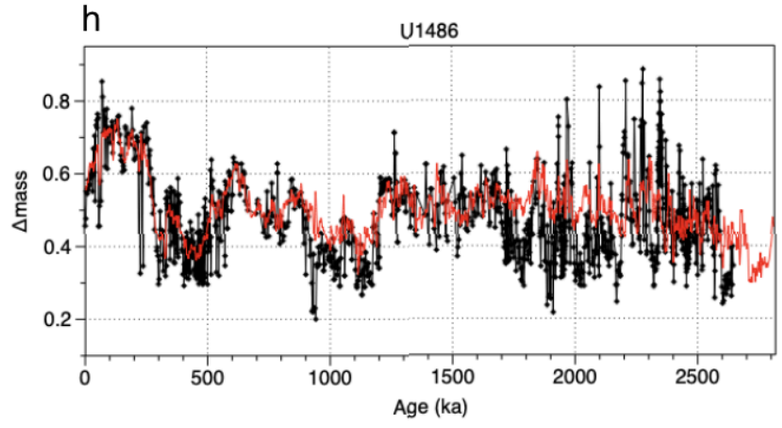


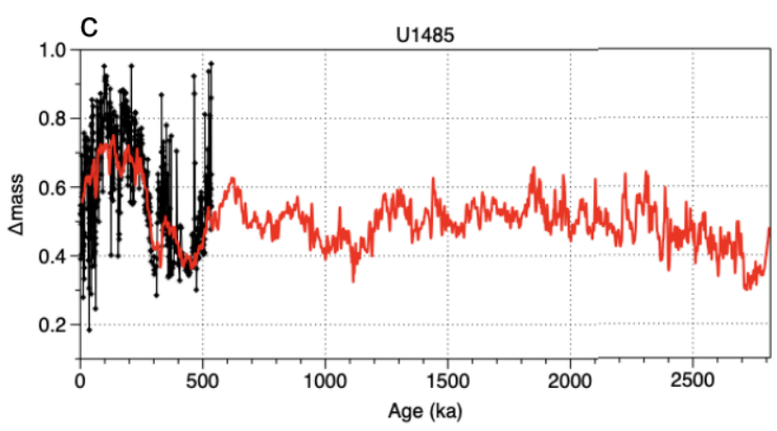


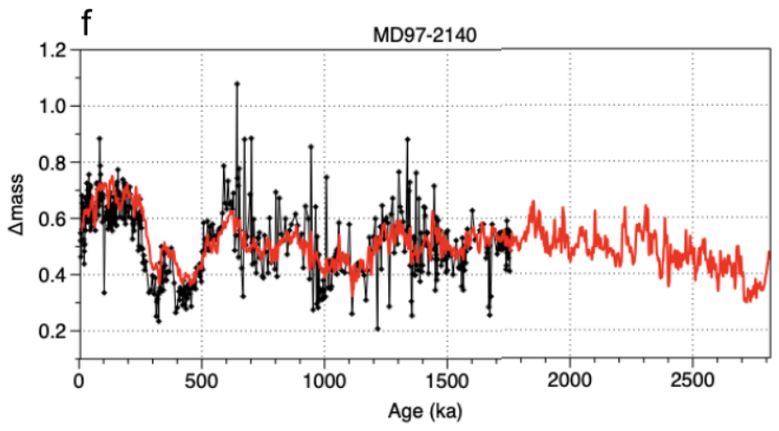


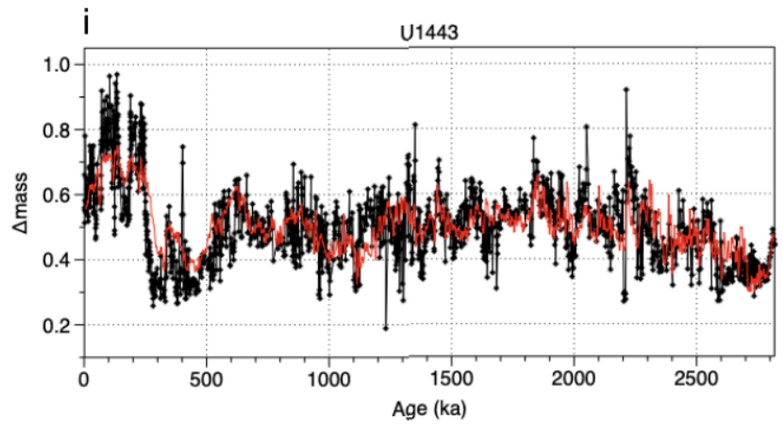


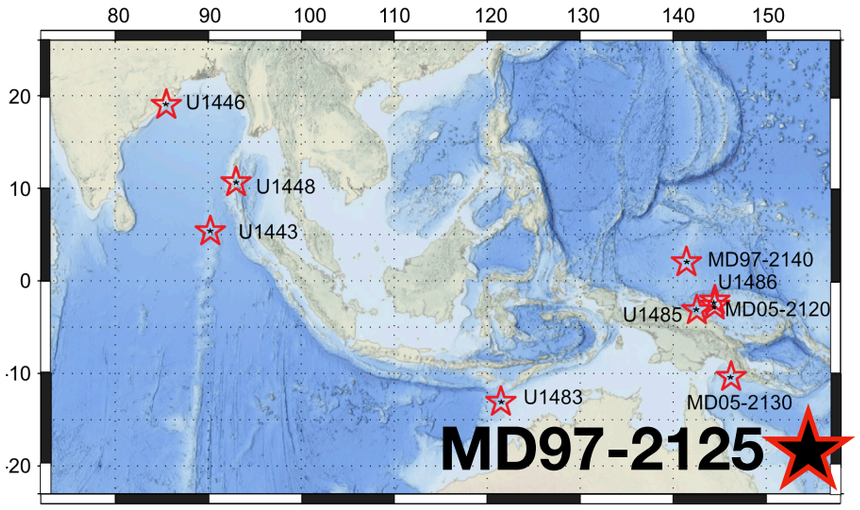


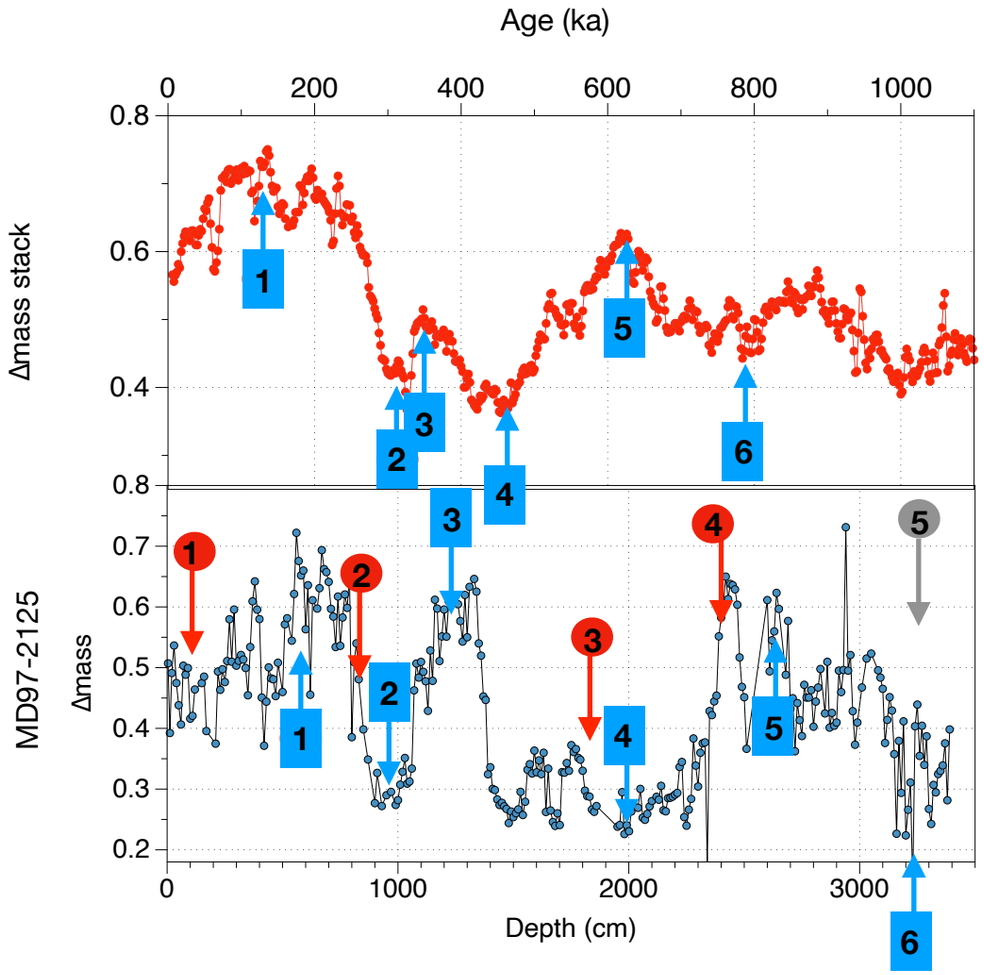












SYRACO Δmass strati.

1-6- Δmass tie points

SYRACO Biostratigraphy

1- Base acmé *E.huxleyi* = 0.9 ka

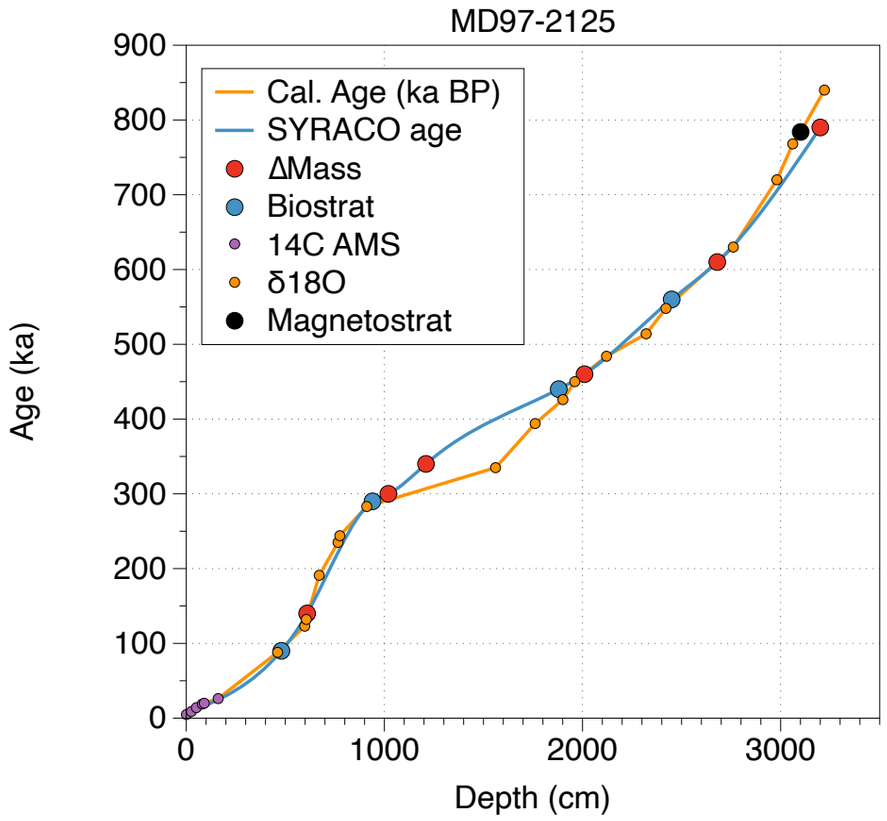
2- Top acmé *G.caribbeanica* *FAD E.huxleyi* = 290 ka

3- LAD *P.lacunosa* = 440 ka

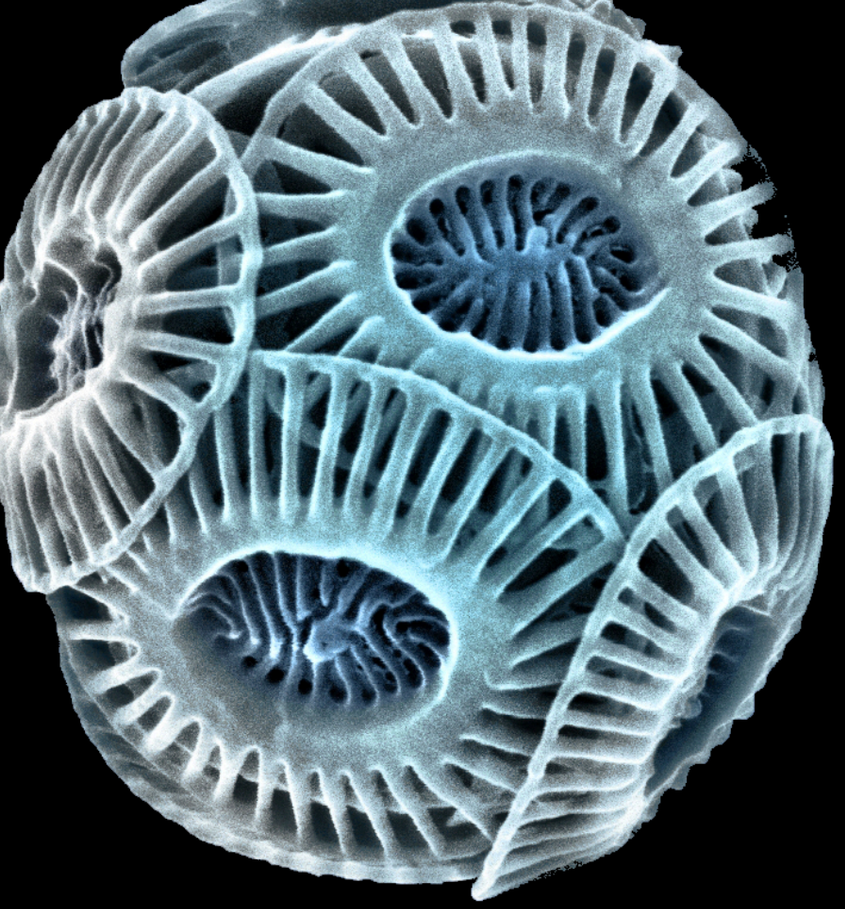
4- Base acmé *G.caribbeanica* = 580 ka

Magnetostratigraphy

5- Brunhes-Matuyama



By combining the classical biostratigraphy done by SYRACO, and the quantitative biostratigraphy using Δmass, it was possible to draw a stratigraphic scheme as precise as the isotopic stratigraphy on that core



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Conclusions

-SYRACO is a robust tool that has been used for 20 years, but that is in constant evolution since its start.

-It is used in stratigraphy for 5 years by TOTAL (Pau, France) since it is able to recognize all Cenozoic species that are grouped in 71 classes.

-Recent technical advances have increased its efficiency and it can now reach the level of species recognition.

-Stratigraphy based on coccolith shape evolution will be a new direction for high resolution quantitative biostratigraphy