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DIPARTIMENTO
DI FISICA E GEOLOGIA

Past climate lesson for future

Simonetta Cirilli, Roberto Rettori, Amalia Spina, Andrea Sorci, Luigi De Dominicis, Nicola Mitillo, Marco Urbani

Piano Triennale della Ricerca e Terza Missione (2021-2023) : Ambito «*Earth System and Global Changes*»

Tematiche:

Cause e conseguenze delle variazioni climatiche nella storia del pianeta Terra

Sviluppo di nuovi approcci nei sistemi di cattura, stoccaggio e riconversione della CO_2

Azioni di Ateneo

Linea azione 5: Clima, energia e mobilità

WP 5.2 - Cambiamenti climatici: consapevolezza impatto sociale, modelli scientifici e soluzioni tecnologiche

WP 5.1 - Infrastrutture, sistemi energetici e produttivi a basso impatto ambientale

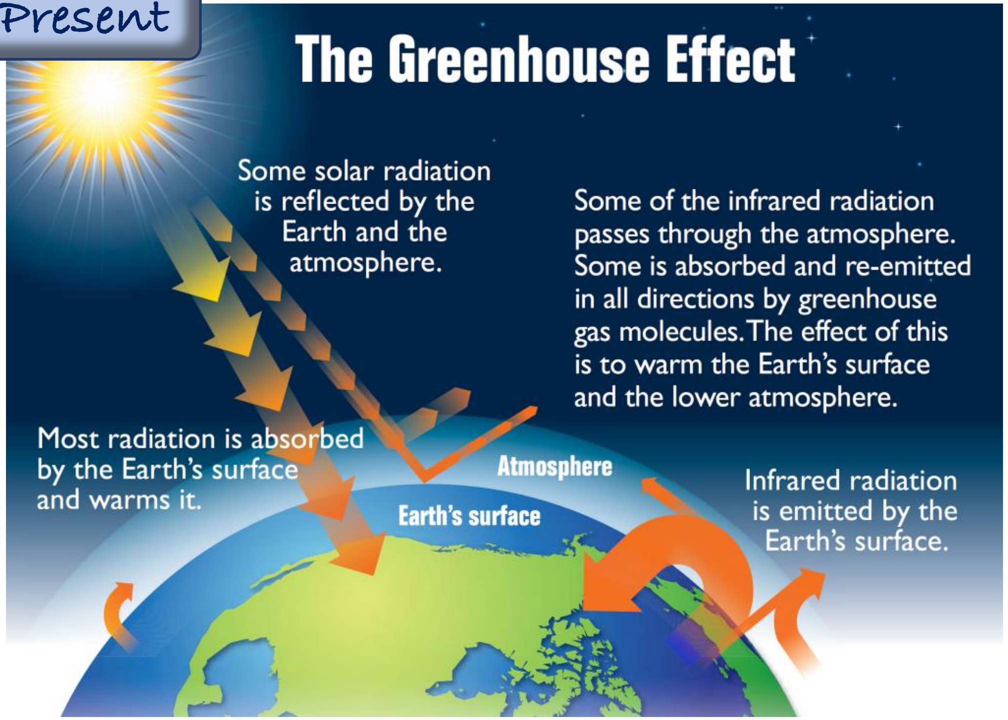
Linea azione 2: Cultura, creatività e società inclusive

WP 2.2 - Tecniche e strategie di comunicazione della conoscenza

WP 2.3 - Individuo e società: benessere e inclusione

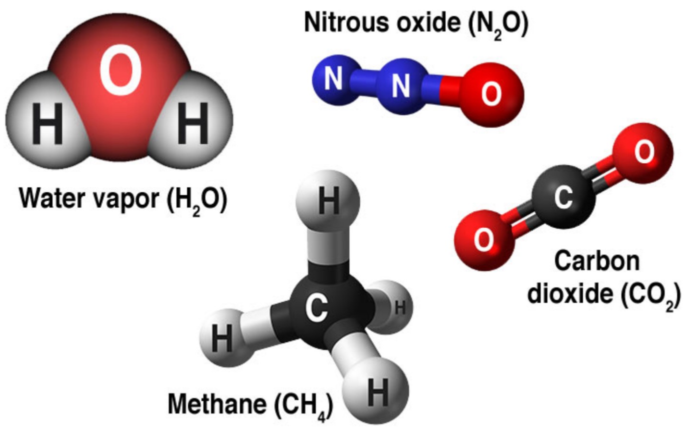
Present

Greenhouse

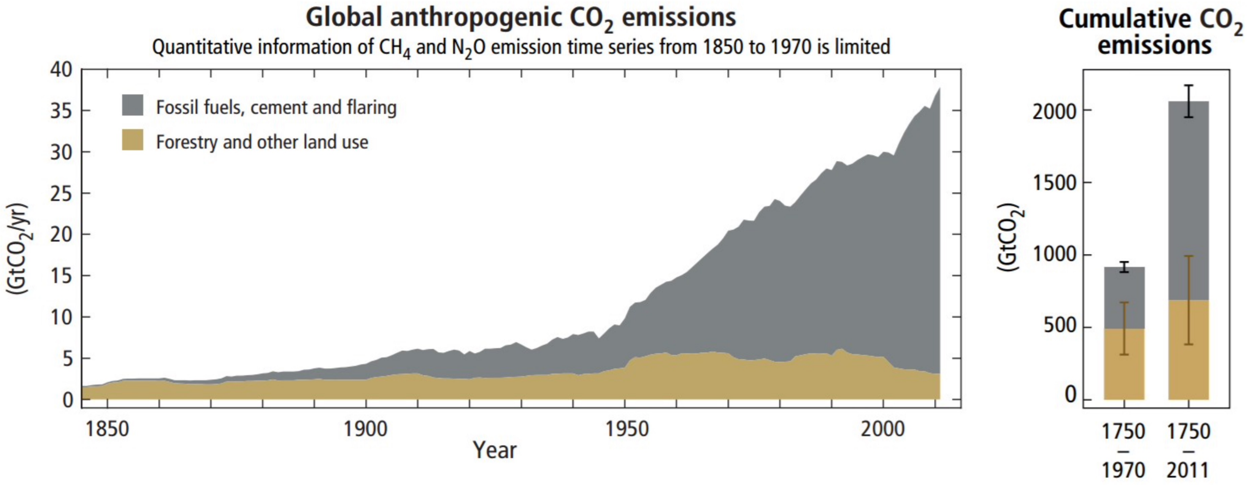


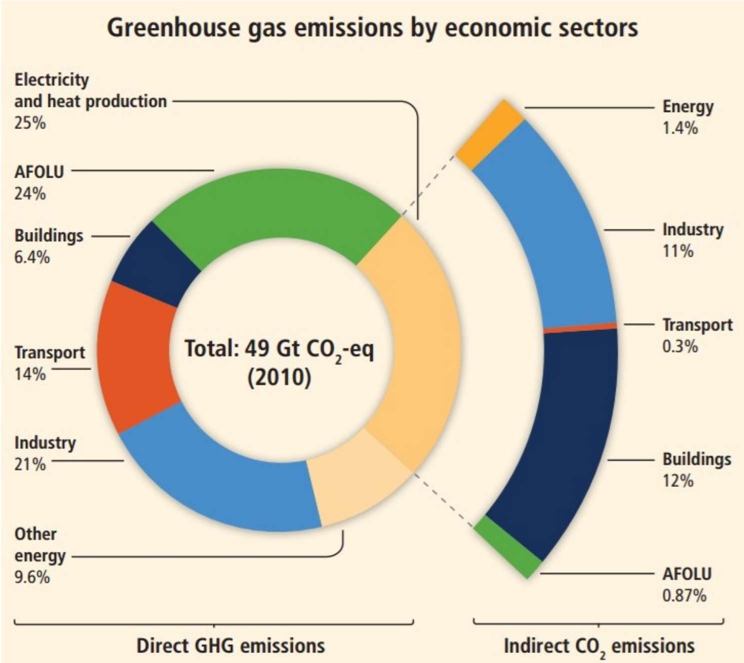
Water vapor is the most abundant greenhouse gas, its abundance in the atmosphere does not change much over time.

CO_2 less abundant but it has a **long residence time in the atmosphere** and added to the atmosphere by human activities

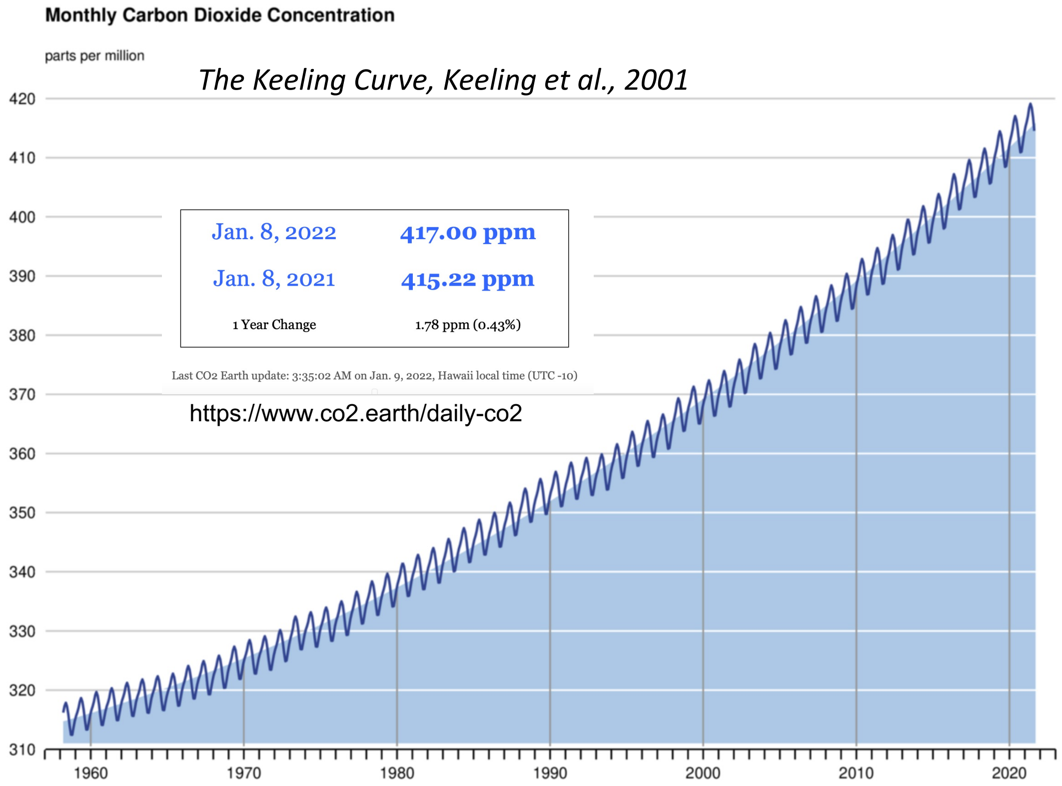


Most common greenhouse gases



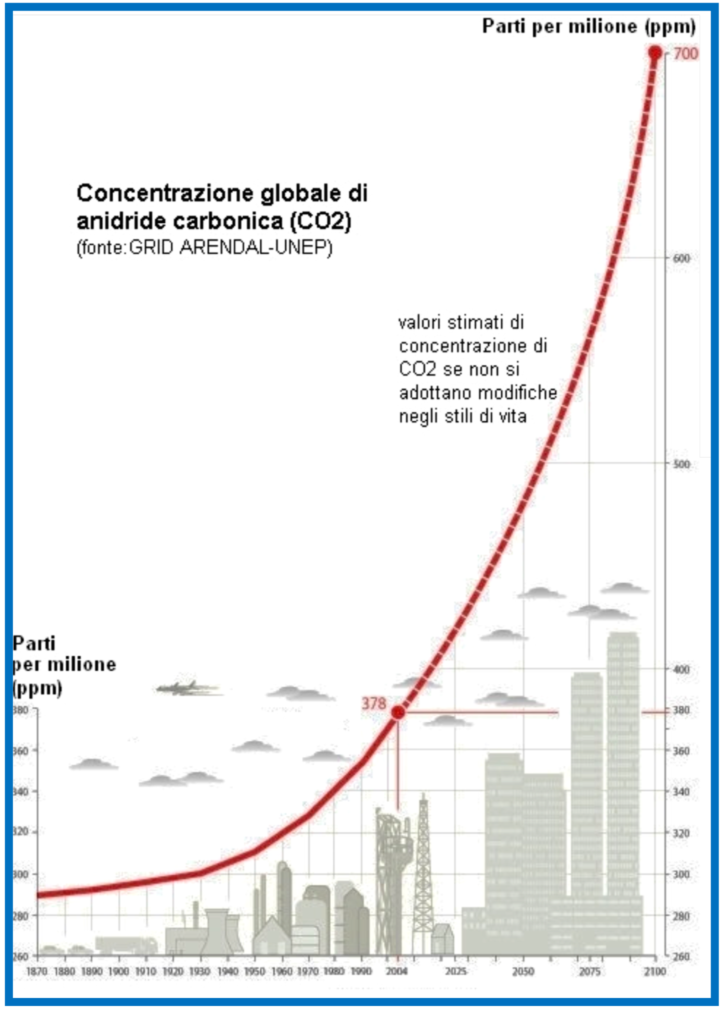


$atmCO_2$ increasing



The $atmCO_2$ concentration is predicted to rise in the 21st century reaching up to **2000** ppm at rates ~100x faster than has occurred over the past

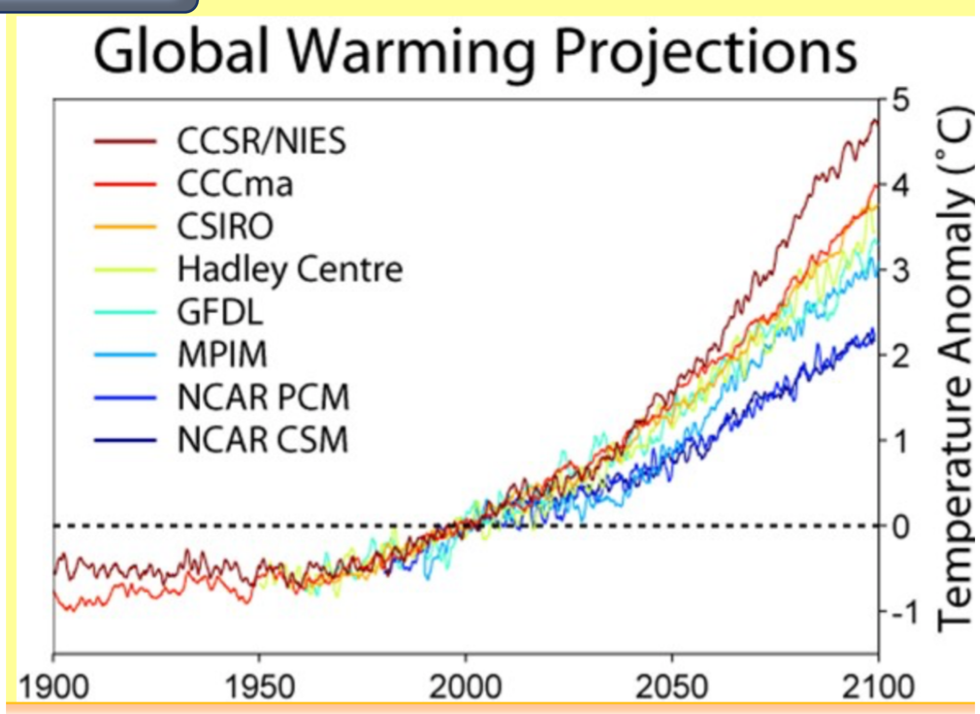
At the present rate of increase, $atmCO_2$ may reach 600 ppm by the end of this century, a value that appears not to have been typical for at least **24My**



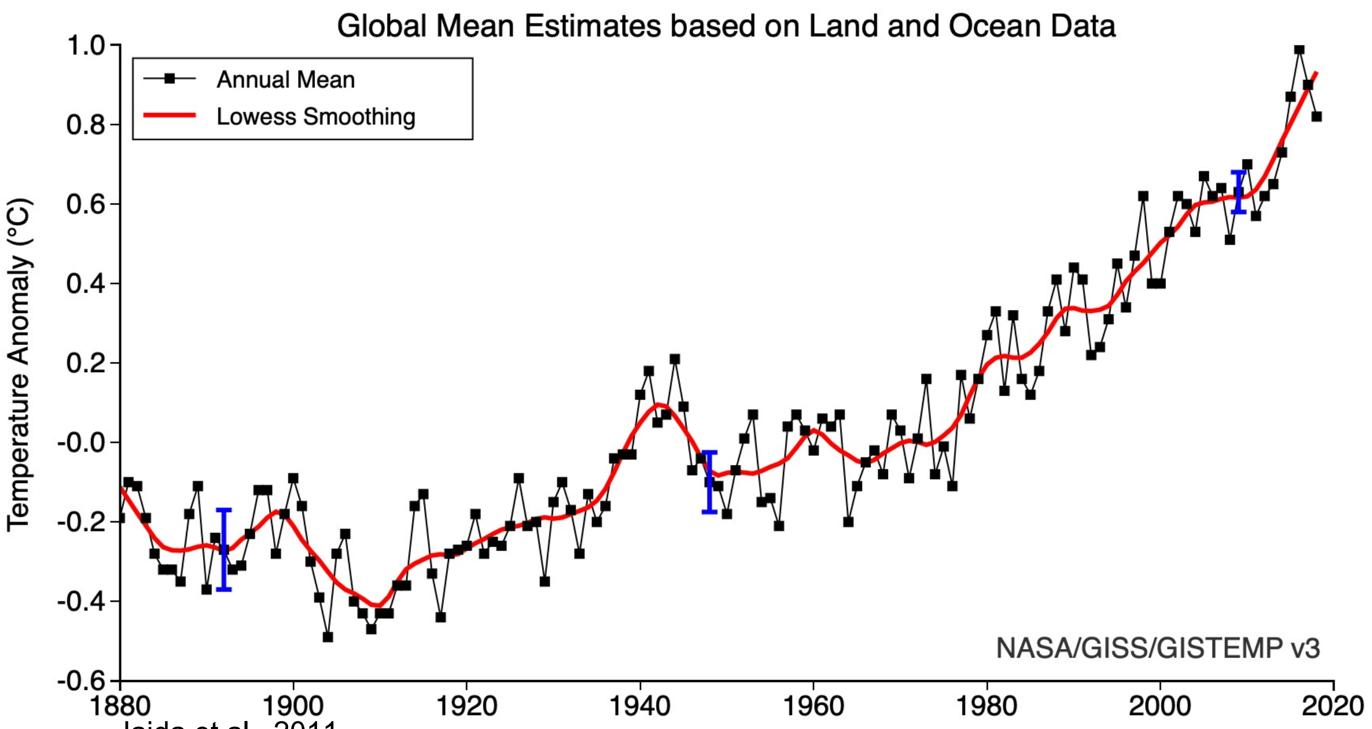
compromise ecosystem resilience, global thermal-stress and alteration of ocean chemistry, triggering responses of marine biota in terms of extinction, innovation and/or temporary adaptations

CO_2 has increased by 40% since 1750 and the rate of increase has been the fastest during the last decade

Global Warming

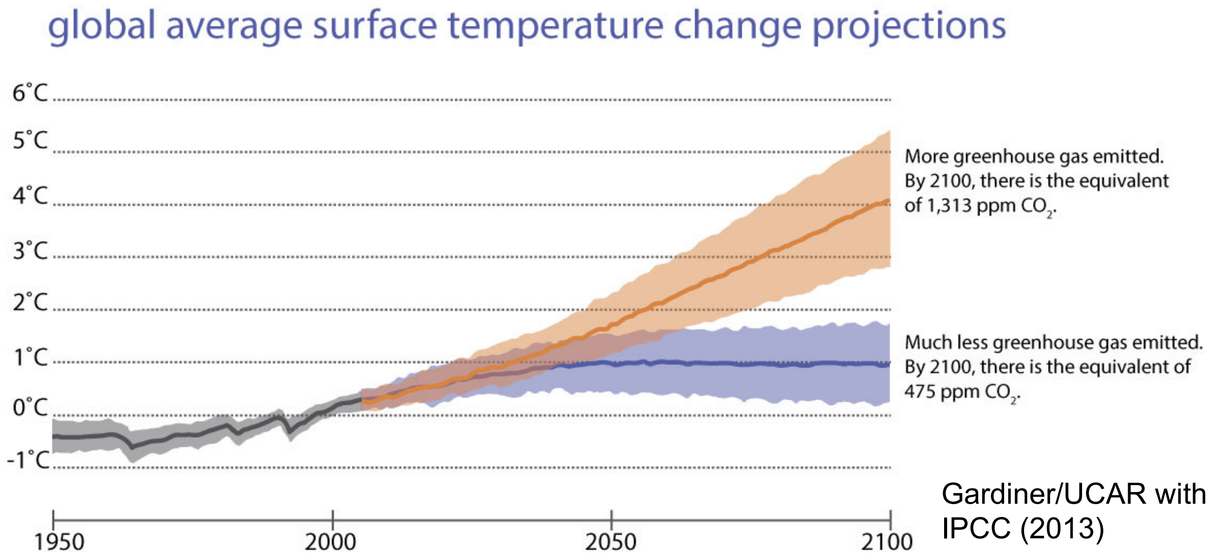


Jajda et al., 2011



Jajda et al., 2011

Land-ocean T° index, 1880 to present. black line: global annual mean; red line: 5-year Lowess smoothing; blue uncertainty bars (95% confidence limit) account only for incomple spatial samples



Gardiner/UCAR with IPCC (2013)

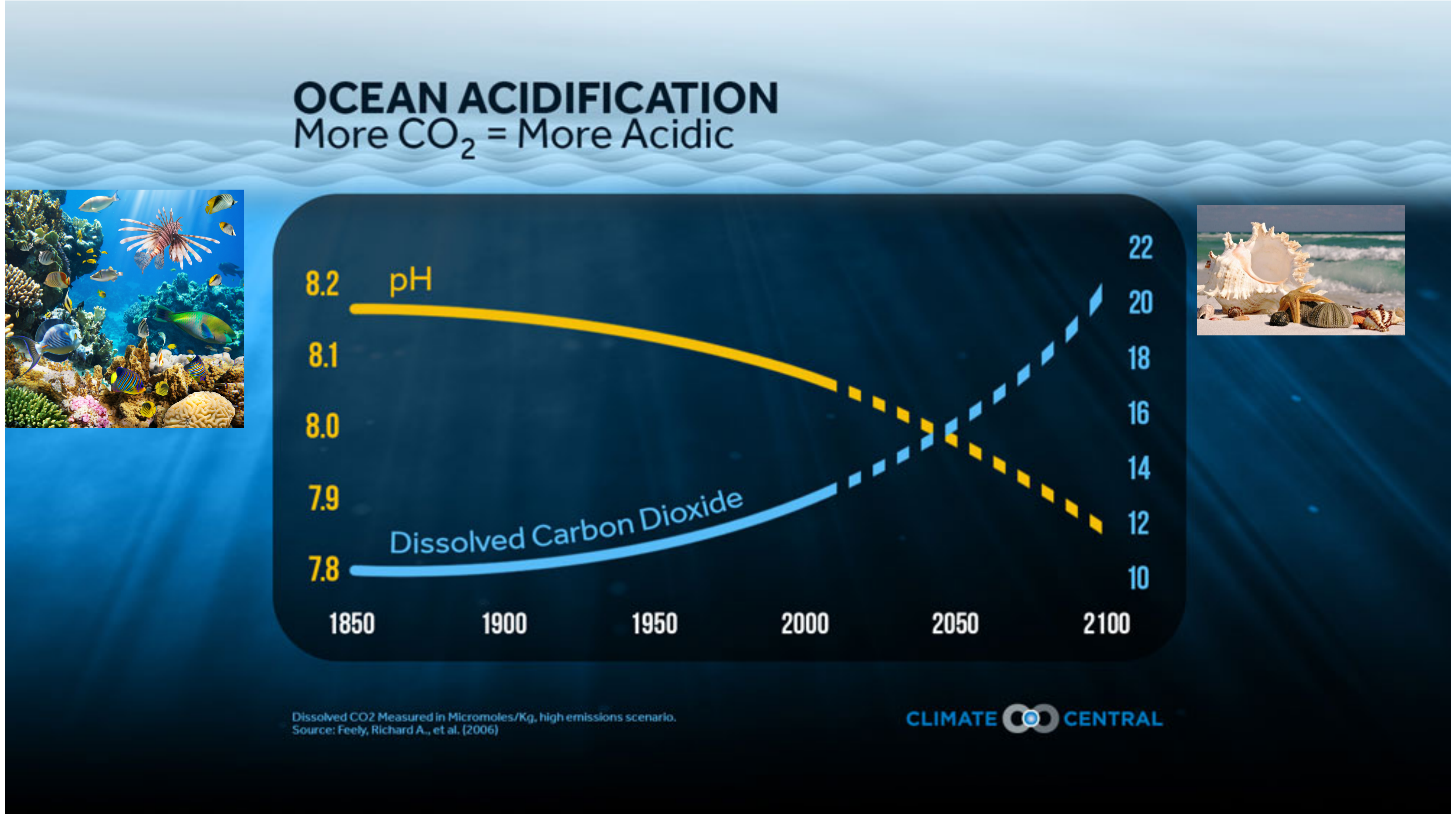
Increasing T up to 5°C in 2100

Present

Ocean Warming and Acidification

The oceans are absorbing about 80% to 90% of the additional heat. The top 2000 m of the ocean will increase in T° of about 0. 8 C at the end of 21 century

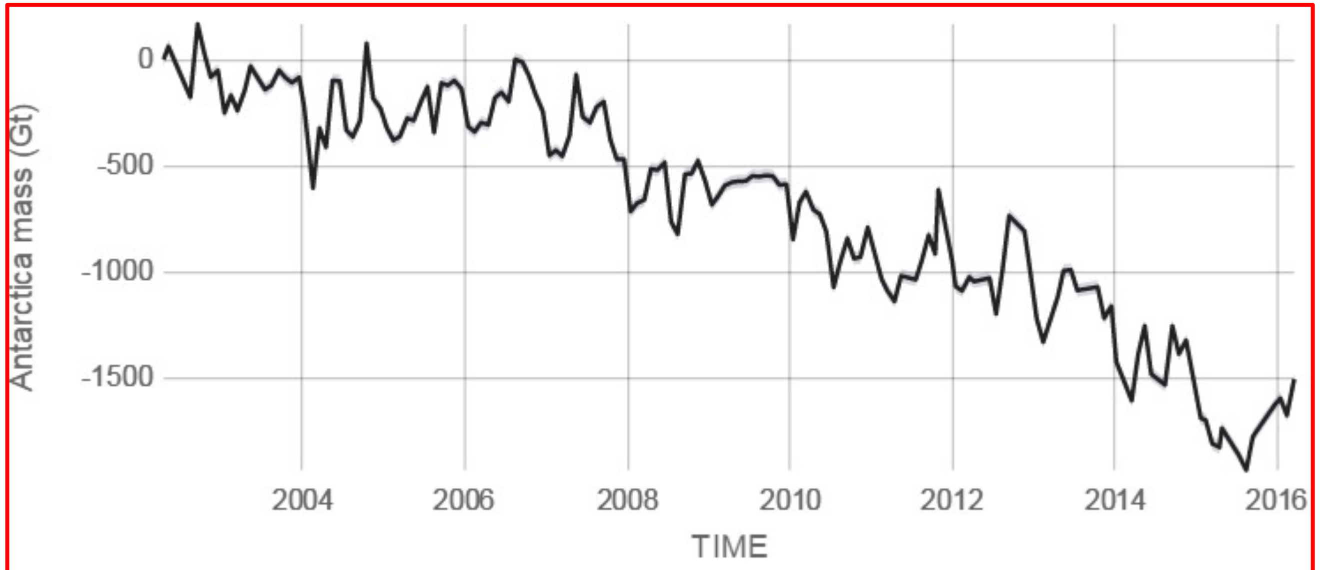
The oceans absorbe about 30% of CO_2, which has an impact on marine organisms that secrete calcium carbonate shells.



Studies on recent ecosystems have demonstrated that abrupt global warming and OA are detrimental for carbonate-secreting organisms and can determine dramatic biotic shifts with the demise of carbonate platforms and coral reefs as well as biocalcification failure of planktonic calcifiers.

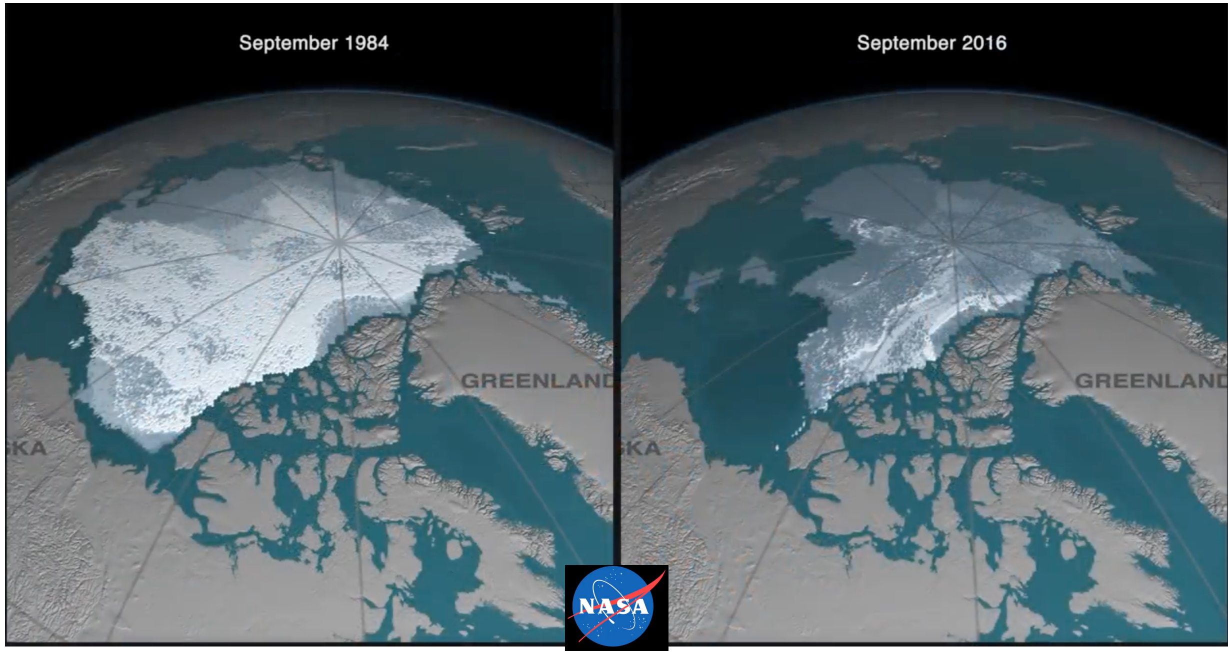
Present

Melting Glaciers and Shrinking Sea Ice



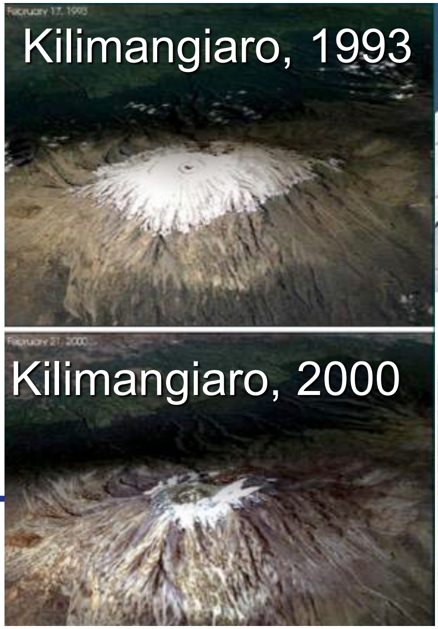
Source: climate.nasa.gov

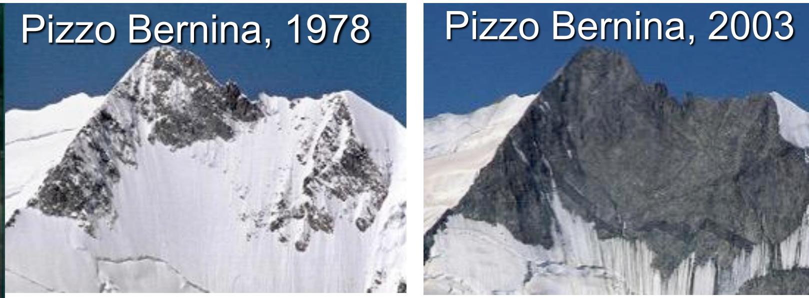
Decline of Antarctic ice mass from 2004 to 2016



Antarctica is melting at 118 gigatons per year

Greenland is melting at 281 gigatons per year





Ghiacciaio del Forni

Present

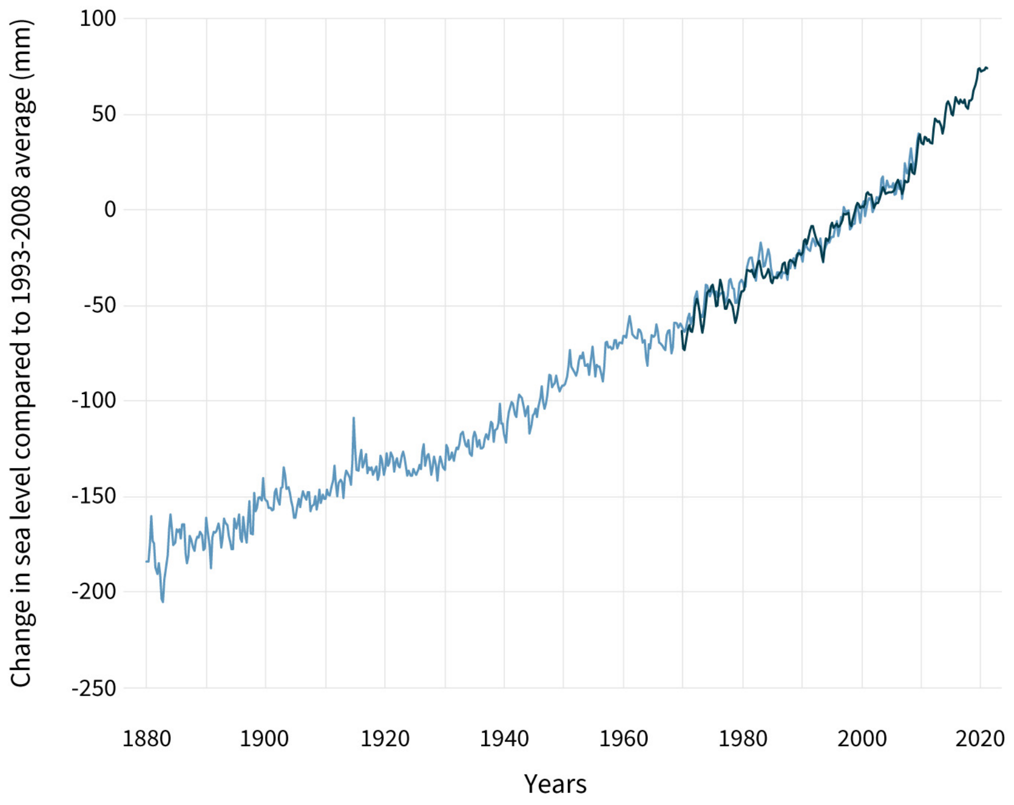
Rising Sea-Level

3.4 mm per year

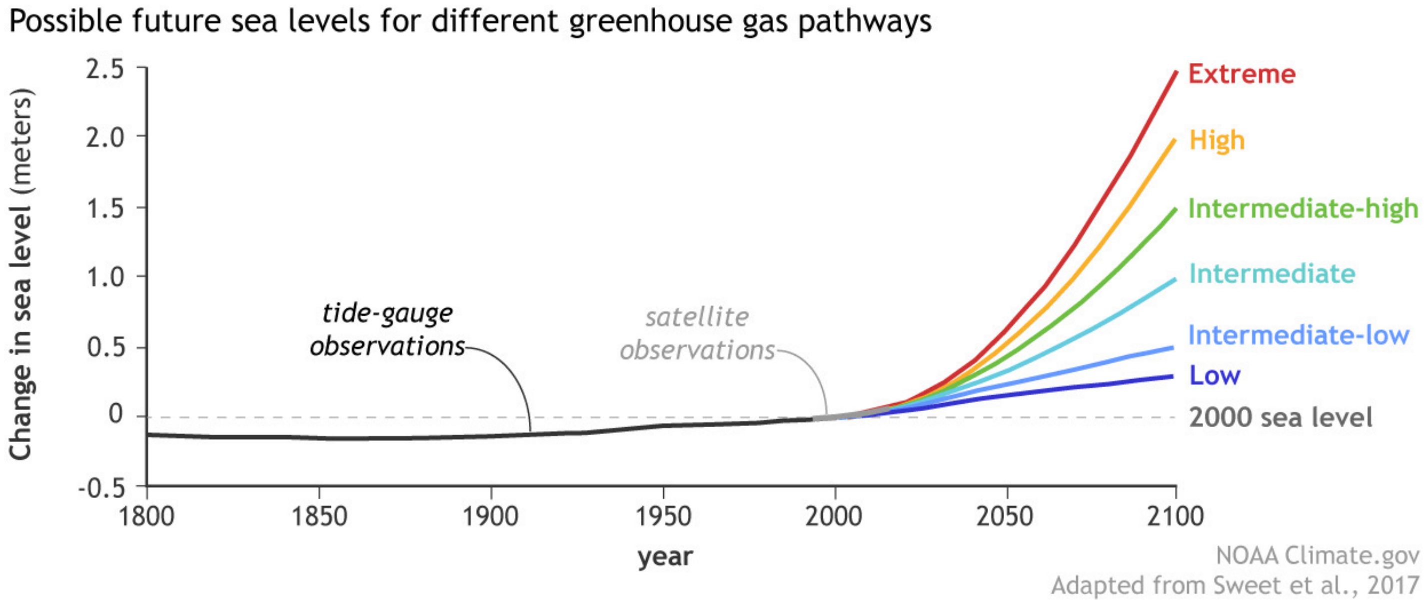
0,8 - 1 m end 21° century

Causes: melting of glaciers and thermal expansion, since 1970, account for 75% of the sea-level rise

GLOBAL SEA LEVEL



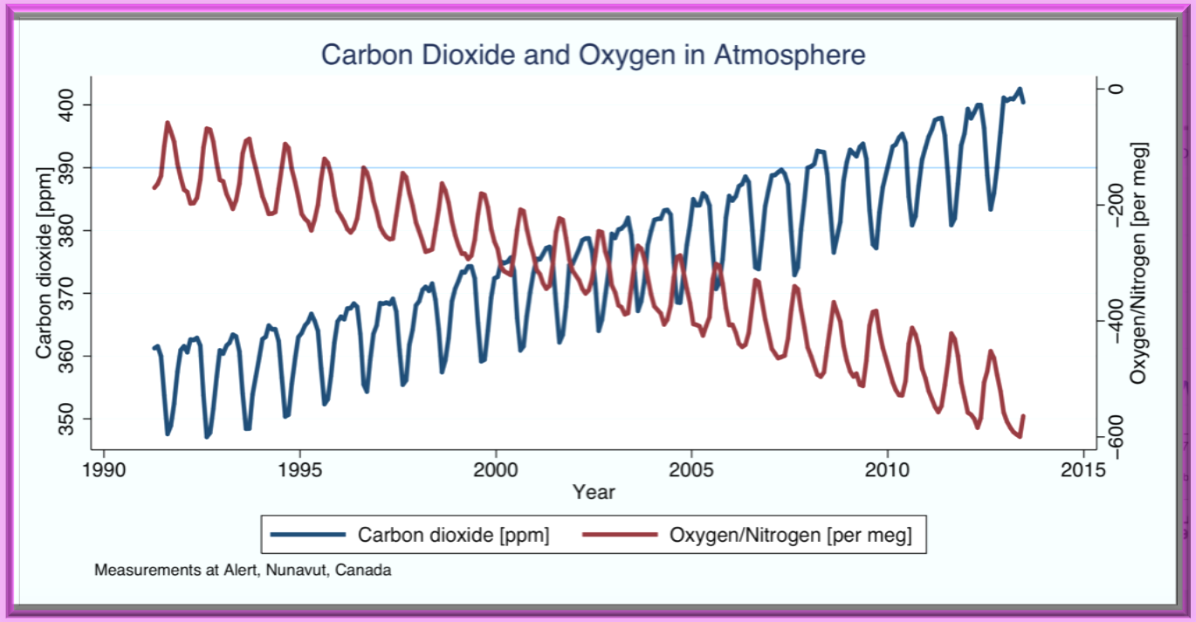
Church and White, 2011 (light blue line) and University of Hawaii (dark blue).



Observed sea level from tide gauges (dark gray) and satellites (light gray) from 1800-2015, with future sea level through 2100 under six possible future scenarios (colored lines). The scenarios differ based on potential future rates of greenhouse gas emissions and differences in the plausible rates of glacier and ice sheet loss. NOAA Climate.gov graph, adapted from Sweet et al., 2017.

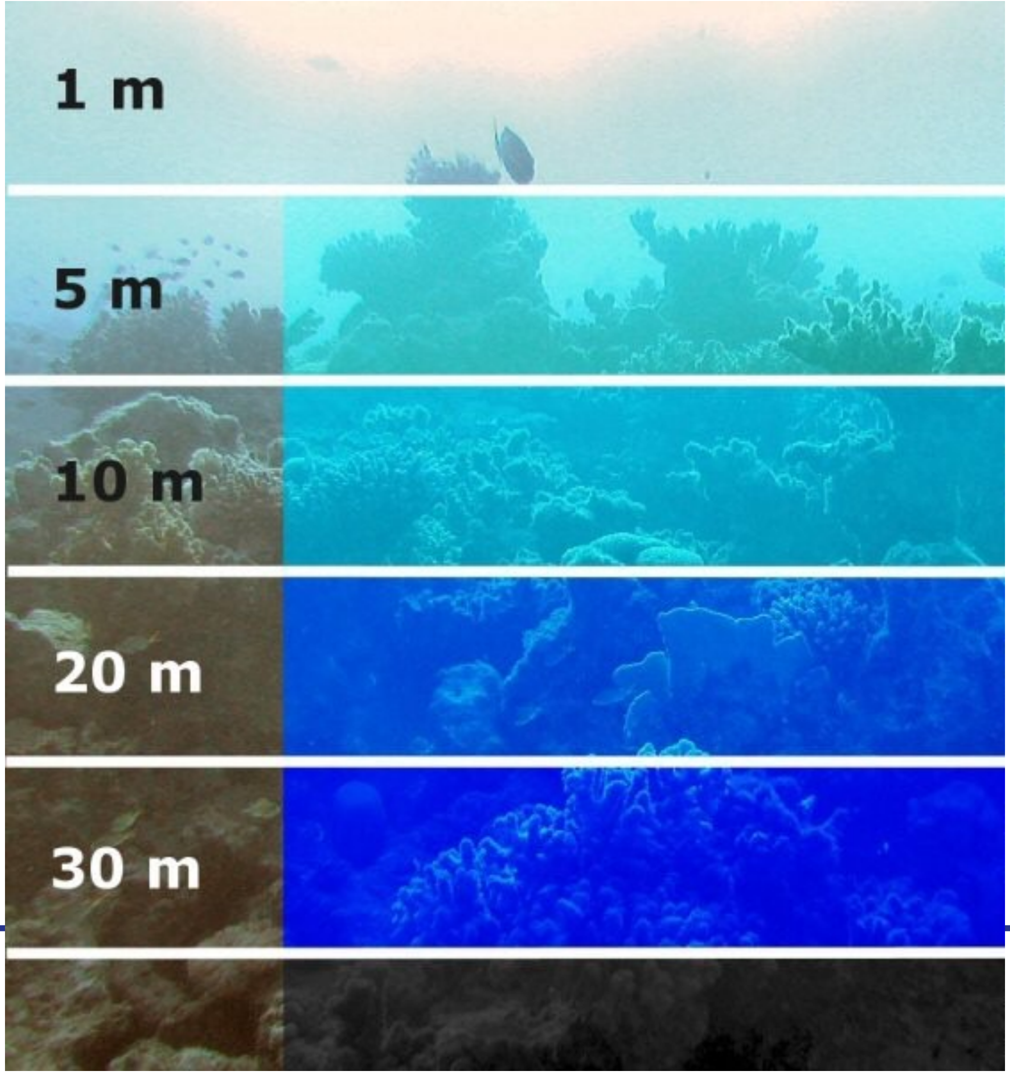
Present

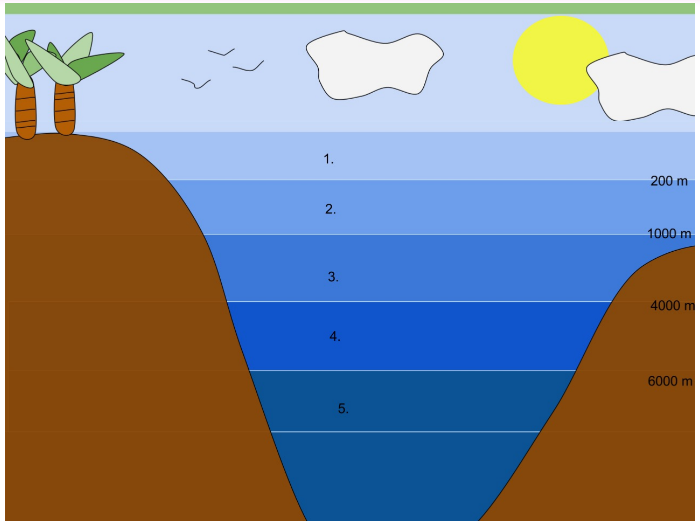
atm O_2 lowering



Acidification combined with warmer temperature and lower oxygen levels is expected to have severe impacts on marine ecosystems

Water stratification and anoxia



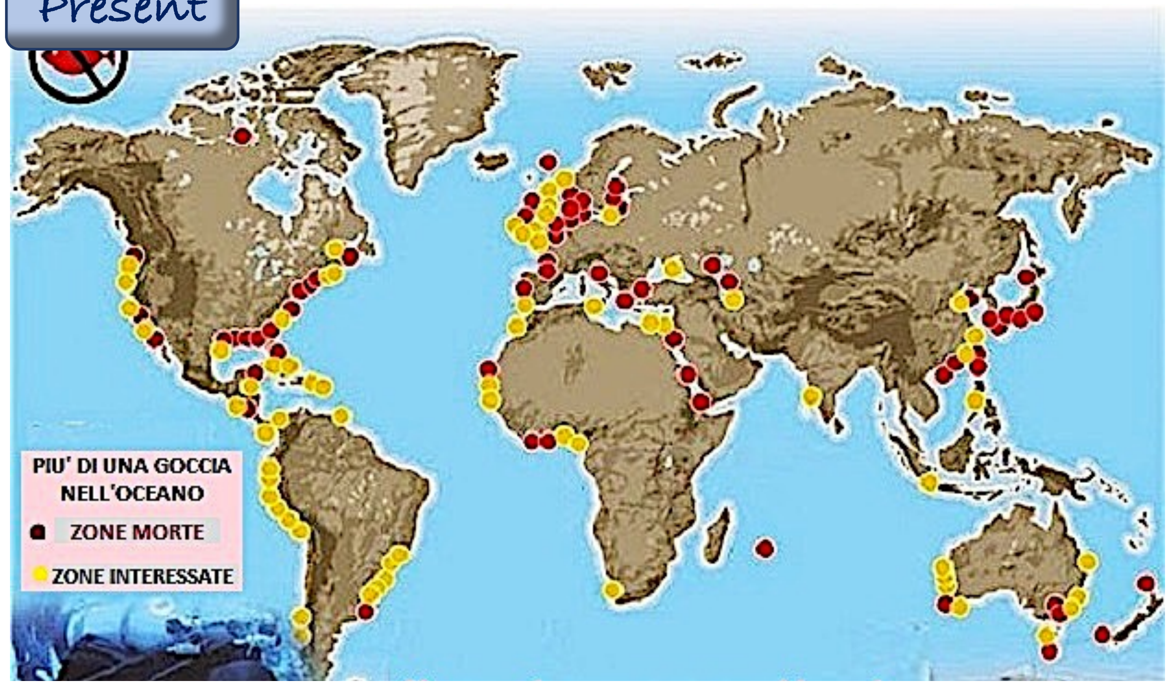


O_2 lowering:

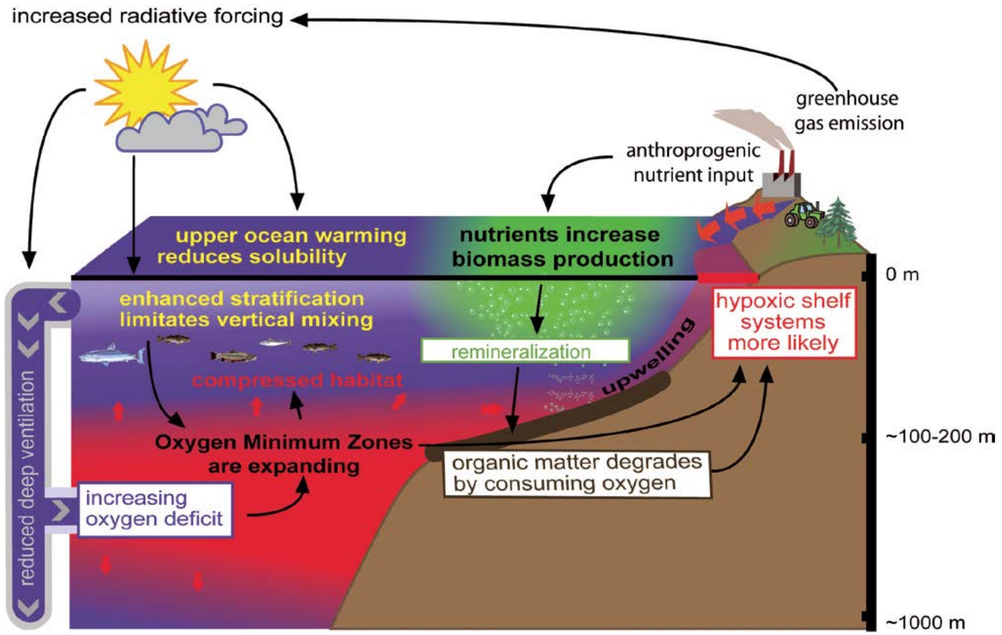
- Atmosphere: 0,1 % in the last 100 years
- Oceans: more than 2% in the last 50 years
- 1% to 7% within 2100

(Schmidtko et al, 2017, Nature Letter)

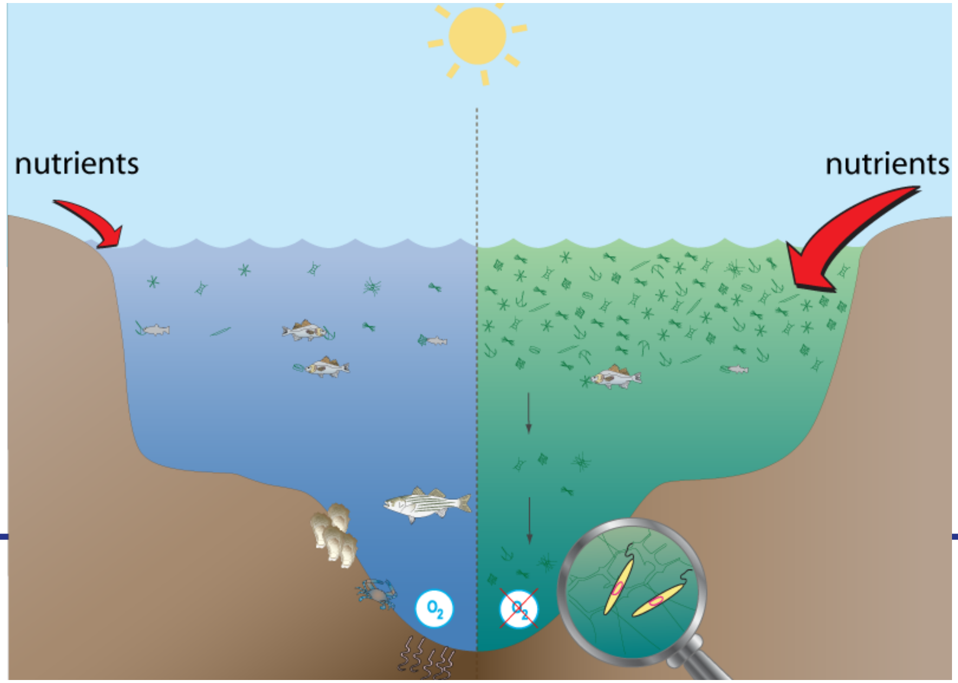
Present



Schematic of interaction of open ocean oxygen minimum zone (OMZ, red) with hypoxic shelf system and dead zones on continental shelves of eastern ocean boundaries



modified after Stramma et al., 2010, Stramma and Schmidtko, 2019



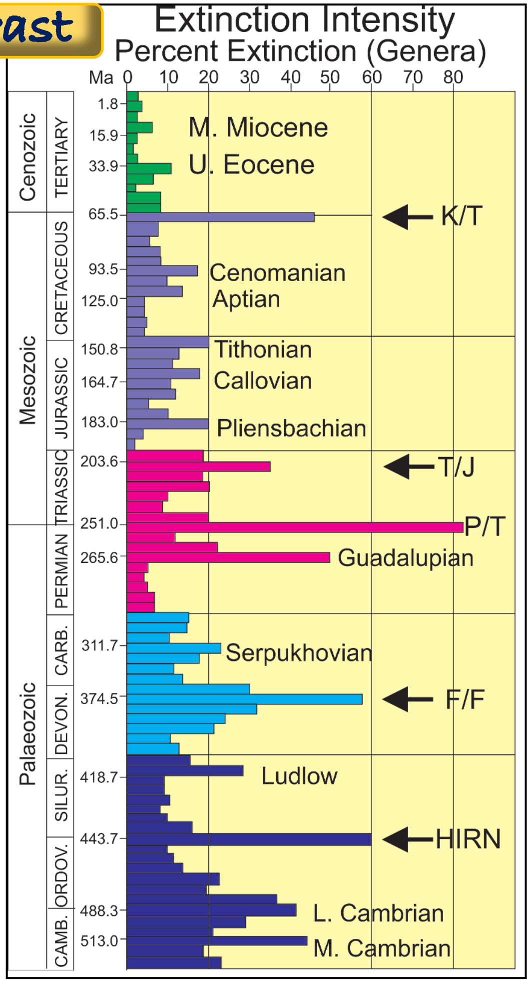
Hypoxia: low or depleted oxygen

+

Eutrophication: increased load of nutrients to estuaries and coastal waters

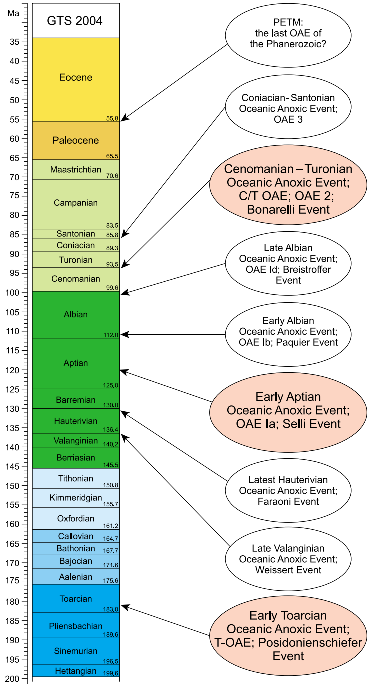
lead to 'dead zones'

Past

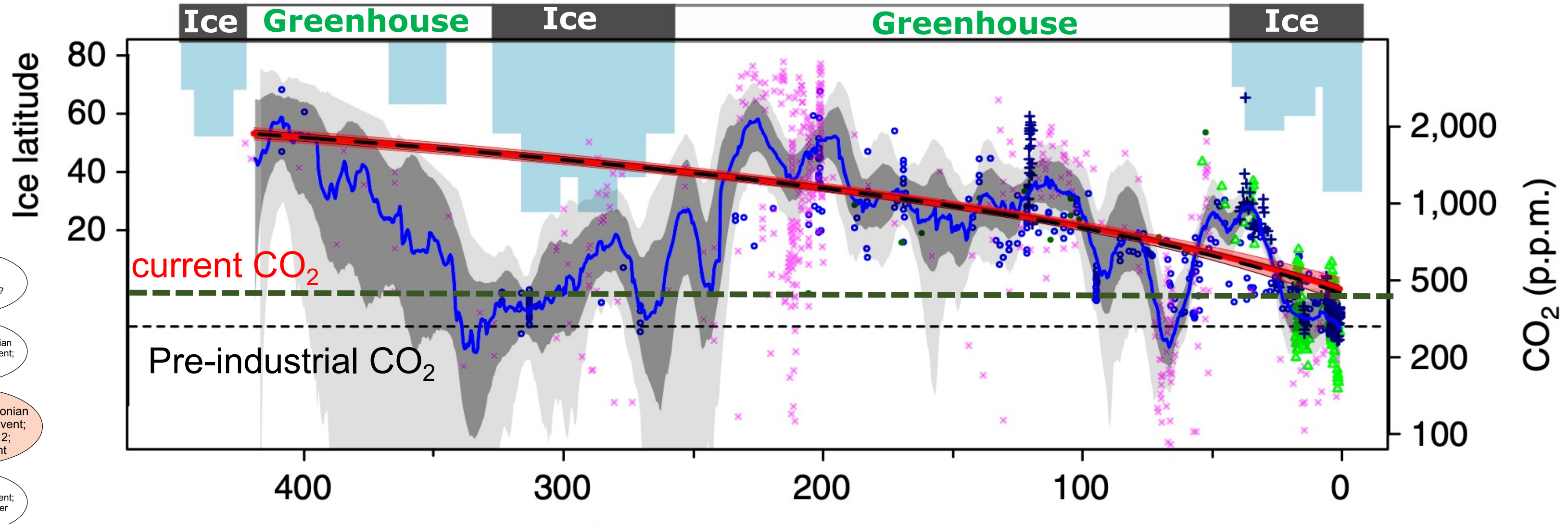


Modified from Keller, 2005

Oceanic Anoxic Event OAE

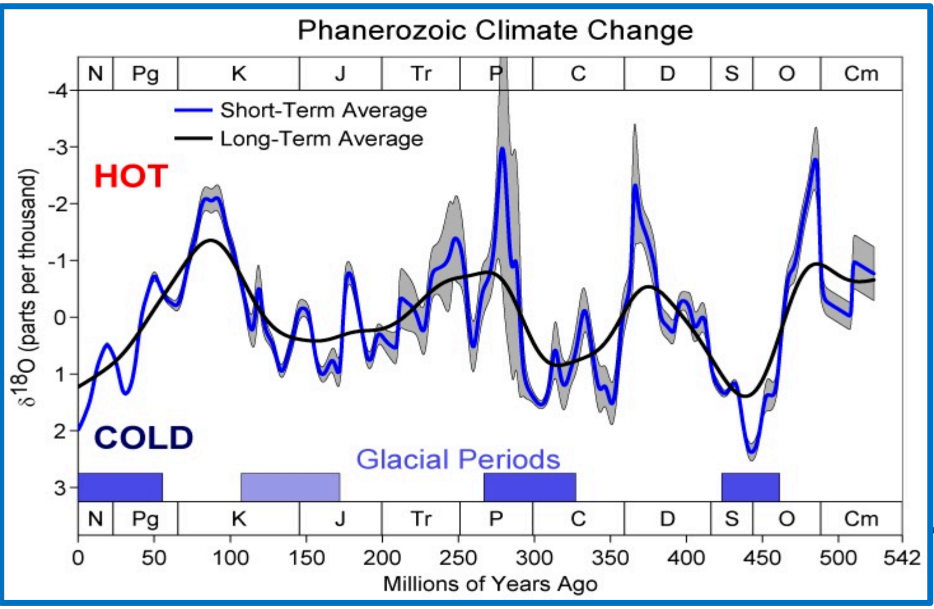


Jenkins, 2010



Modified from Foster et al., 2017

Life on Earth has survived major paleoenvironmental disturbances with evidence of variable engineering and ecological resilience



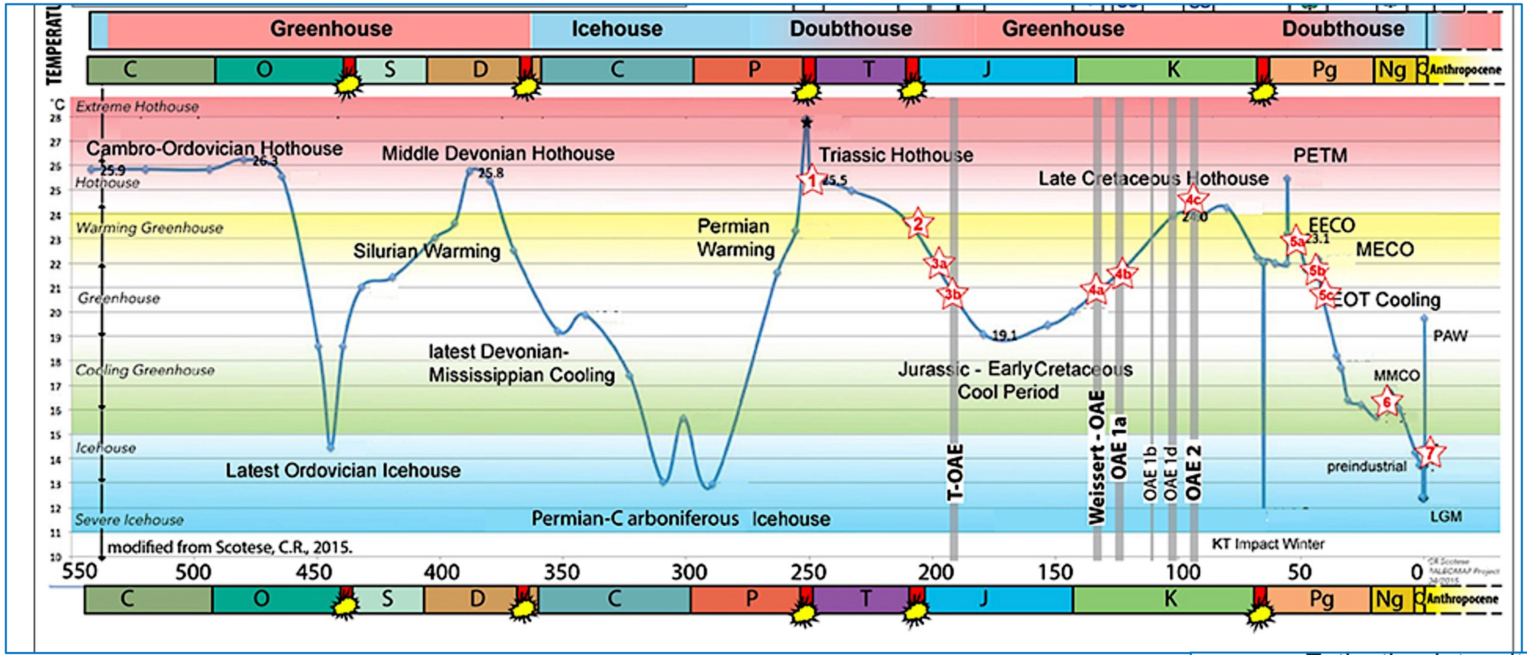
Brink, 2015

Earth has experienced extreme environmental disturbances, with varied tempos and modes of ecosystem resilience, occasionally reaching **tipping-points** that triggered permanent modification in abundance, diversity of marine and continental organisms untill to arrive to mass-exctintion,

Past

Paleoecosystems

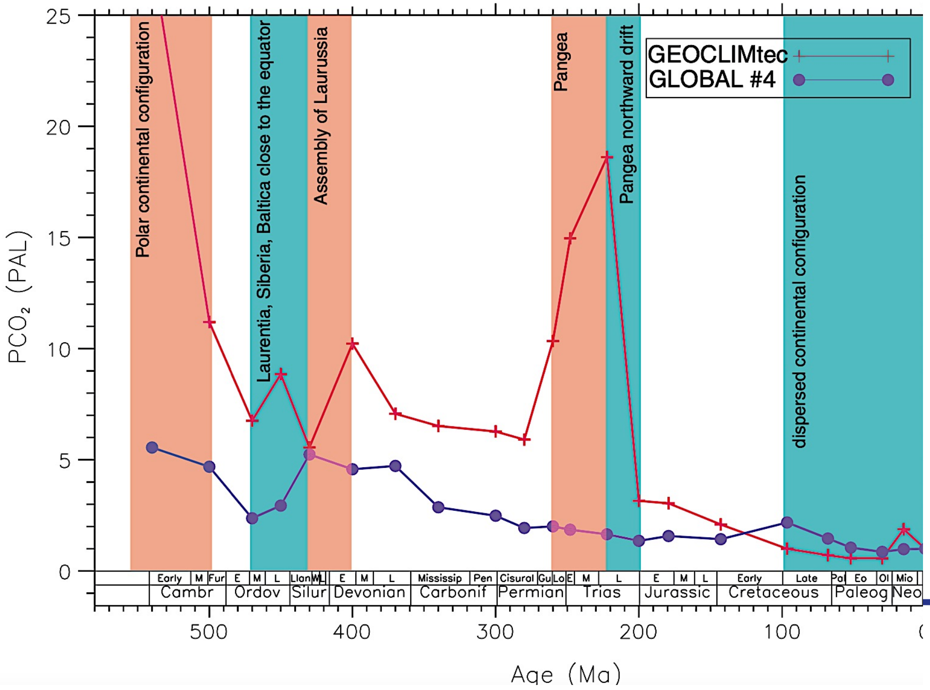
- before pre-disturbed conditions
- during disturbed conditions
- returning to pre-disturbed conditions (recovery)
- shifting to a new regime after reaching tipping-points



Throught a suite of biotic and abiotic archives and geochemical proxies

Data set from PRIN 2017 (CIRILLI et al)

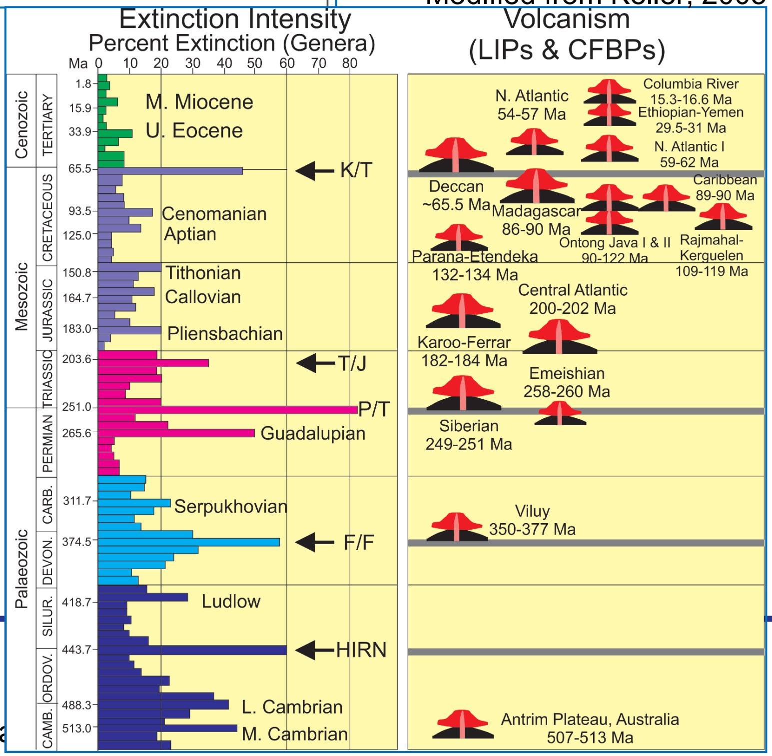
Goddéris et al, 2014



Calculated evolution of the atmospheric CO_2 level over the Phanerozoic

The research aims to reconstruct the tempo and mode of resilience in marine and continental ecosystems when tipping-points trigger permanent modifications and the response of continental and marine ecosystems to excess CO_2 and global warming to produce data for understanding strategies enabling ecosystems to adapt to current (and future) global change

Modified from Keller, 2005

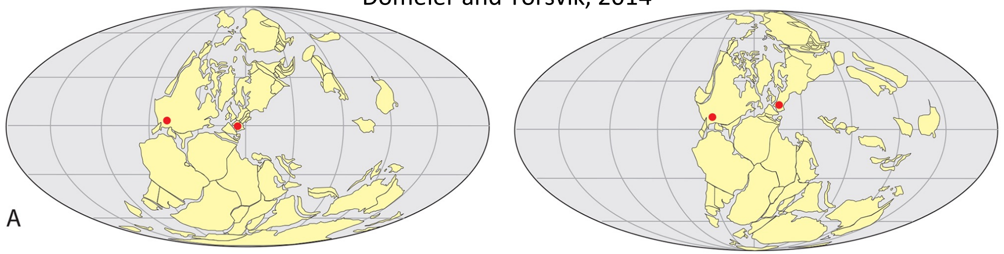


End Permian Mass Extinction
(260-250 My)

Early Permian ~290 Ma

Domeier and Torsvik, 2014

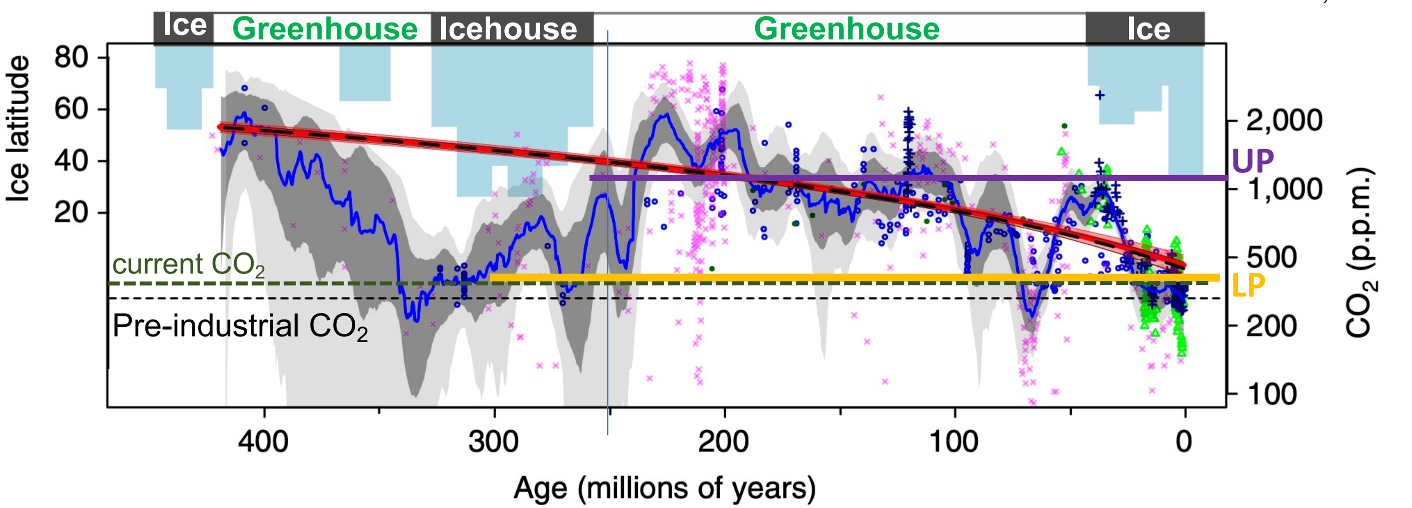
Late Permian ~250 Ma



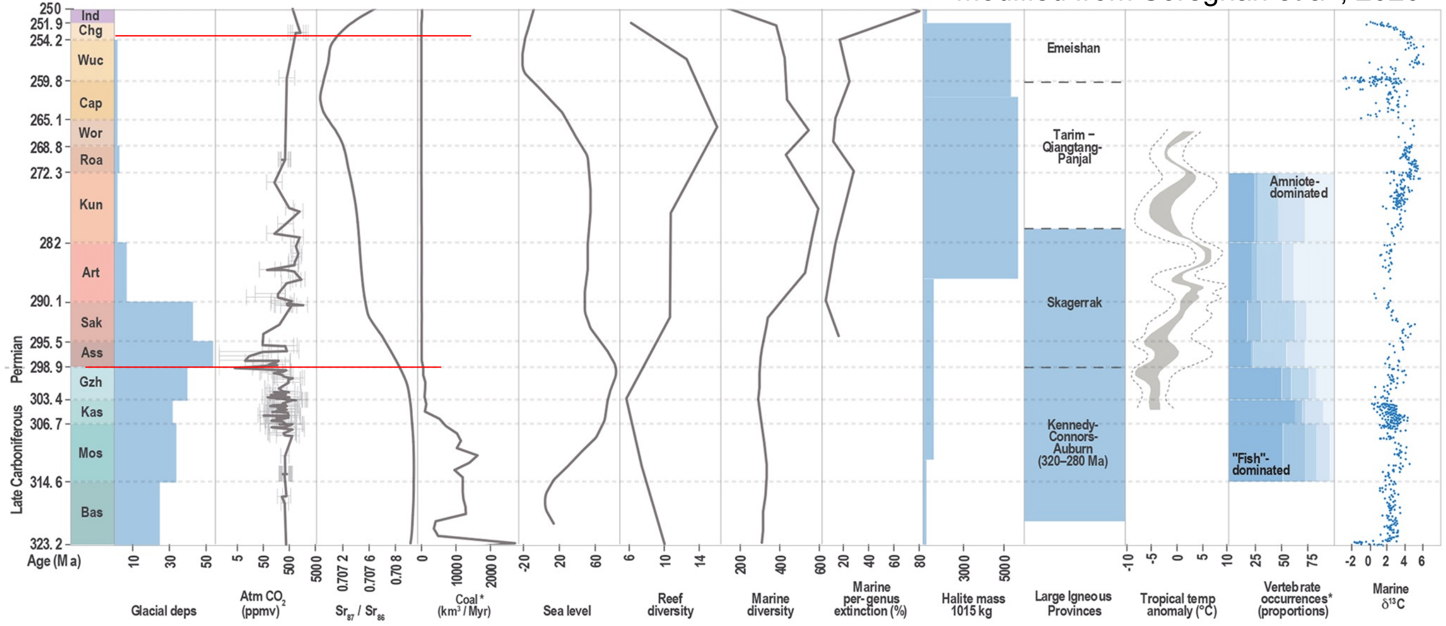
Deep DUST project: A. Spina (PI)-Anadarko (Oklaoma) and Paris Basins

High-resolution CO_2 reconstructions include values comparable to those predicted for Earth's immediate future

Modified from Foster et al., 2017



Modified from Soreghan et al., 2020

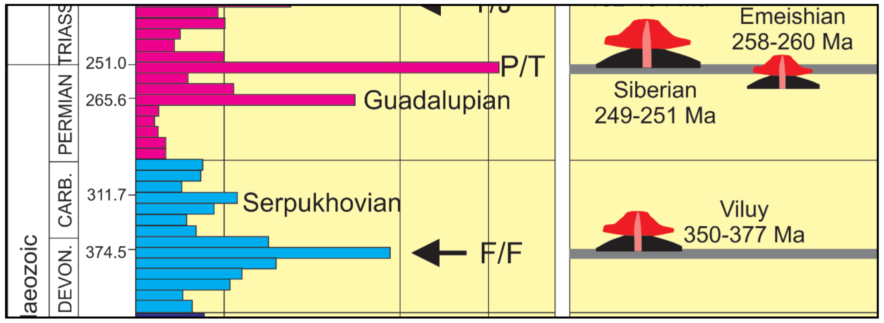


Major trends in the Permian Earth system

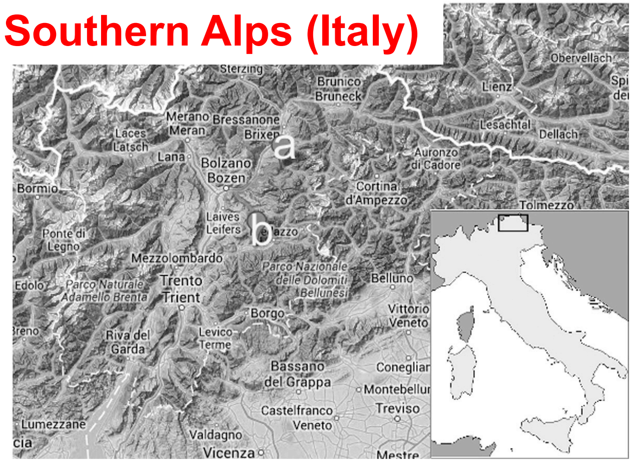
Largest **mass extinction** of the Earth history

Global negative peak of $\delta^{13}C$: Siberian traps, ocean anoxia, methan hydrate dissociation

Increased amount of atmospheric CO_2 linked to the Siberian Traps LIP: global warming and ocean acidification

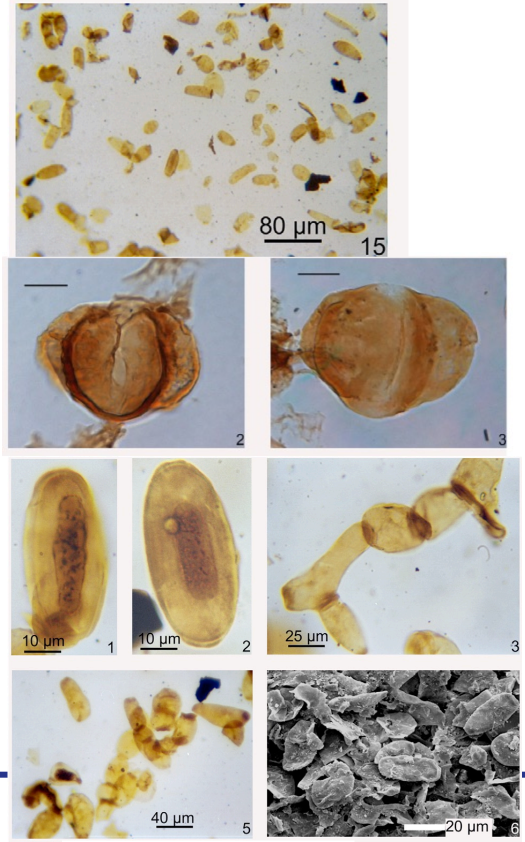


Southern Alps (Italy)

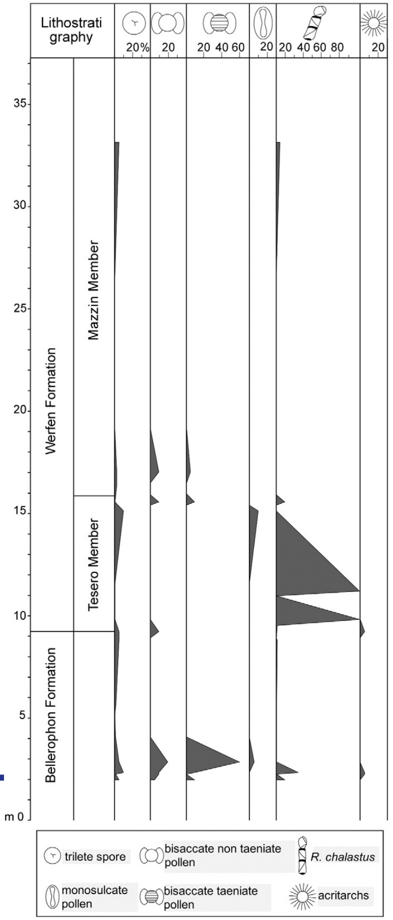


End-Permian mass extinction event

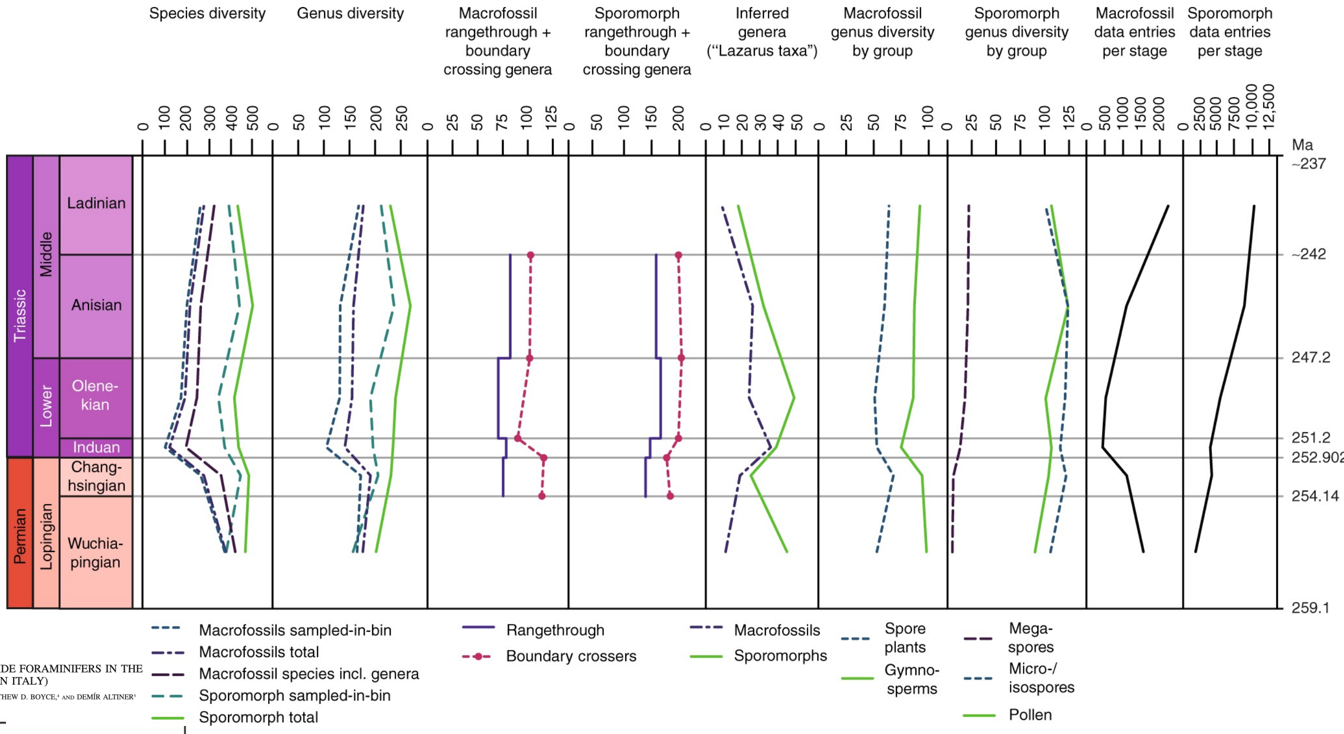
Low or absent plant extinction

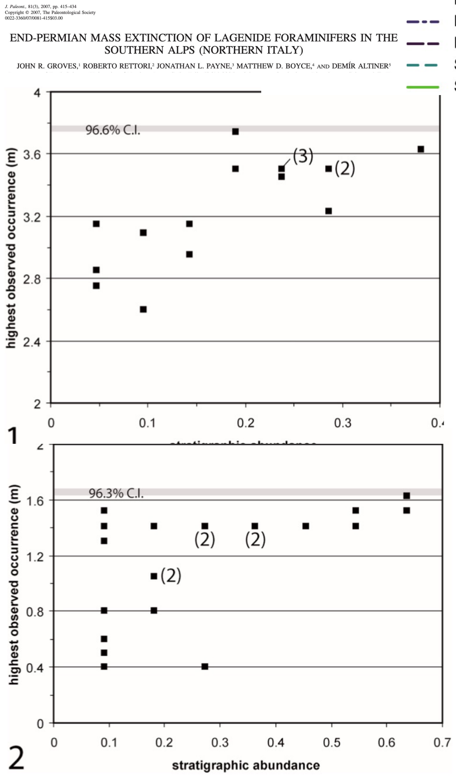


Spina et al. 2015



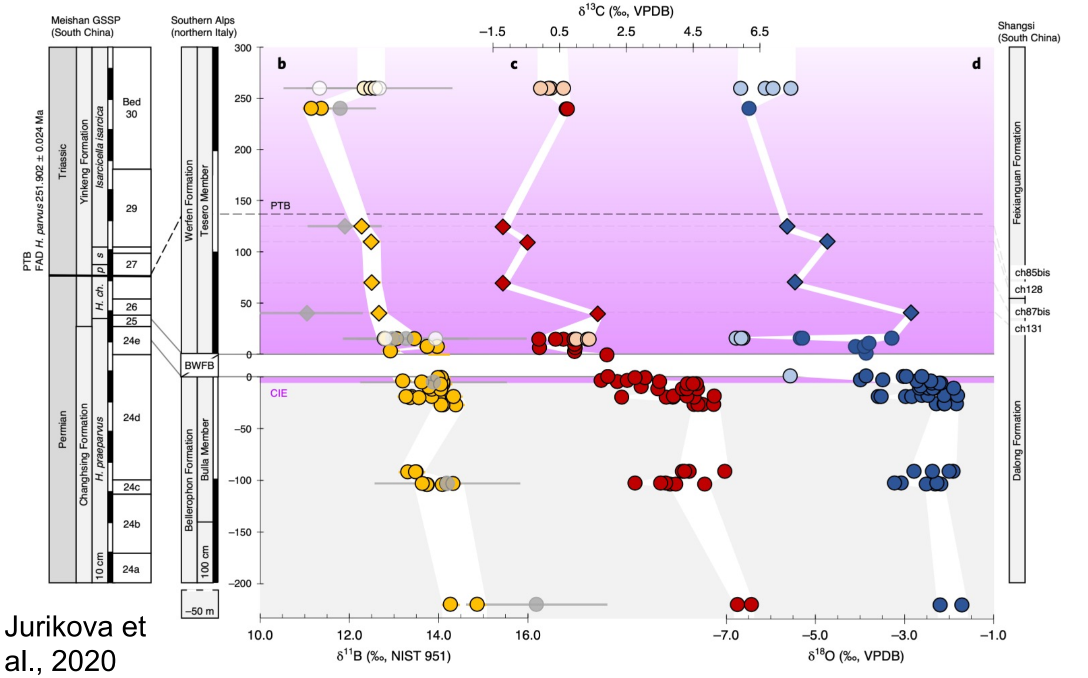
Nowak et al. 2019




J. Paleont., 81(3), 2007, pp. 415–434

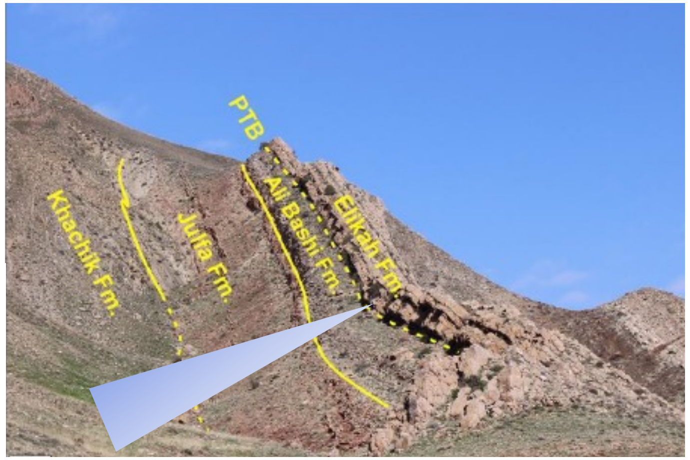
END-PERMIAN MASS EXTINCTION OF LAGENIDE FORAMINIFERS IN THE SOUTHERN ALPS (NORTHERN ITALY)

JOHN R. GROVES, ROBERTO RETTORI, JONATHAN L. PAYNE, MATTHEW D. BOYCE, AND DEMÍR ALTINER



Jurikova et al., 2020

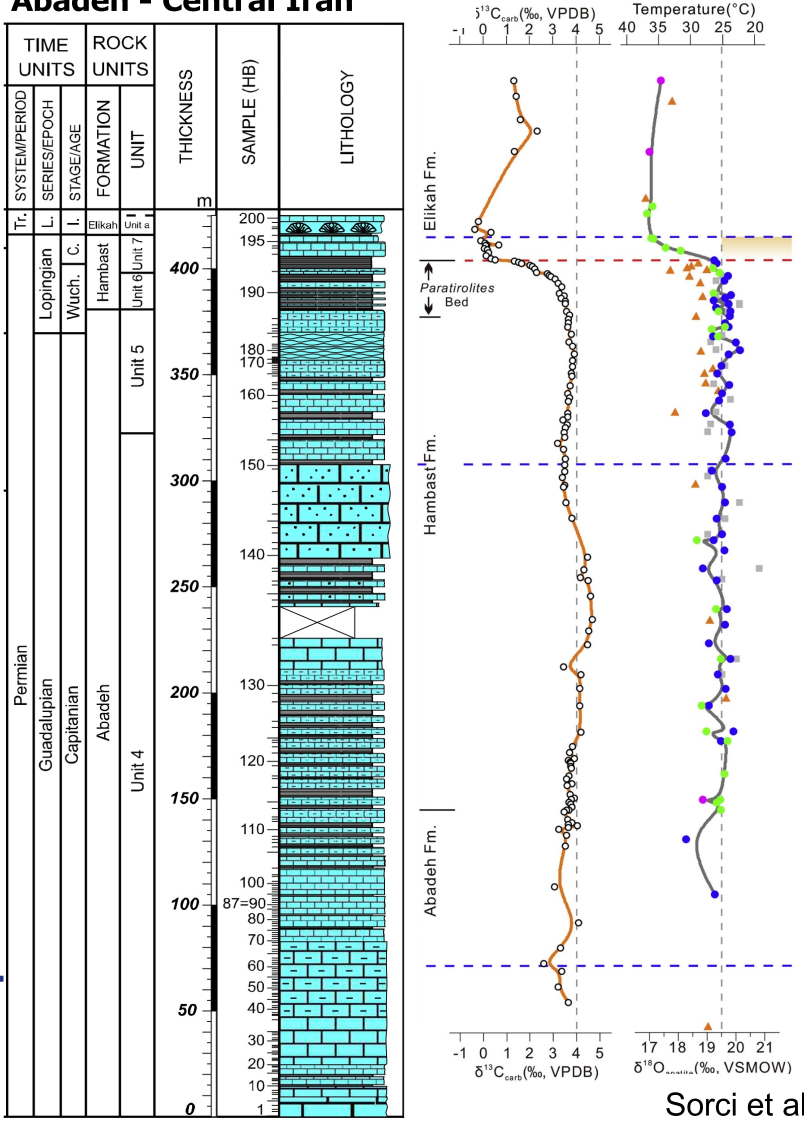
END PERMIAN MASS EXCTINCTION: CENTRAL and NW IRAN

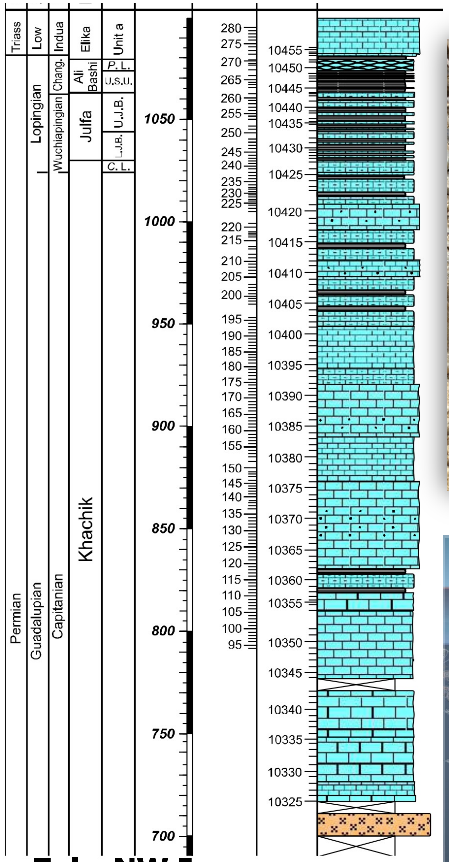


Early Triassic:

- Microbialite bindstone: recovery of carbonate sedimentation and life
- Change in the carbonate factory type: tropical (late Permian) to microbial after mass extinction

Abadeh - Central Iran



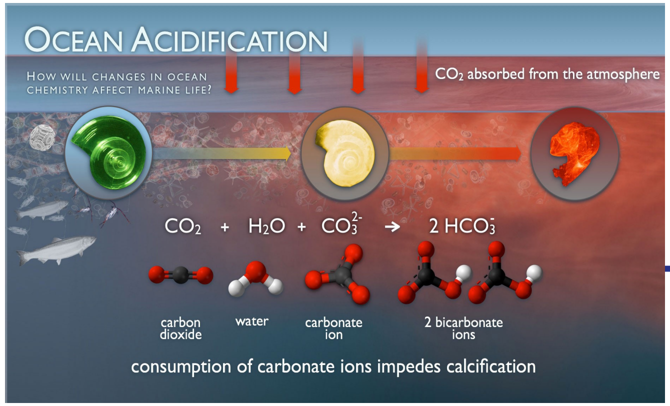


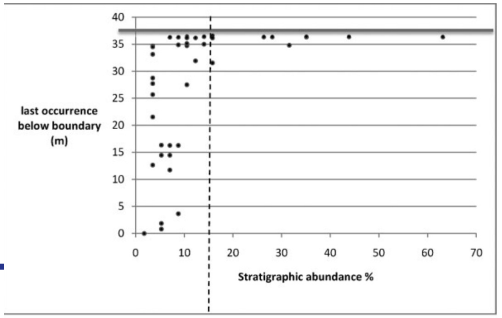
Zal - NW Iran

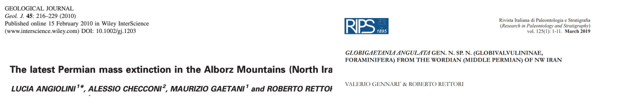
Sorci et al., 2022

End Permian:

- sea level rise
- biocalcification crisis
- mass extinction
- dysoxic to anoxic ocean water







Central Taurides Turkey

EXTINCTION, SURVIVAL, AND RECOVERY OF LAGENIDE FORAMINIFERS IN THE PERMIAN–TRIASSIC BOUNDARY INTERVAL, CENTRAL TAURIDES, TURKEY

Authors: GROVES, JOHN R., ALTINER, DEMİR, and RETTORI, ROBERTO

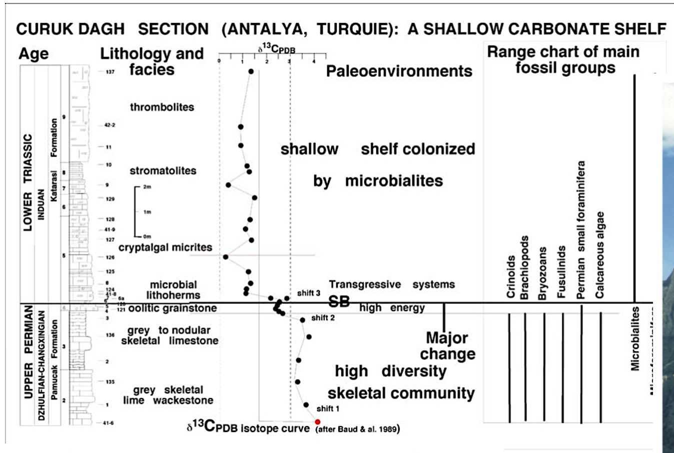
Source: Journal of Paleontology, 79(sp62) : 1-38

Disponible en ligne sur www.sciencedirect.com
ScienceDirect
GEOBIOS
Geobios 40 (2007) 715–729

Original article

Brachiopods and other fossils from the Permo–Triassic boundary beds of the Antalya Nappes (SW Taurus, Turkey)

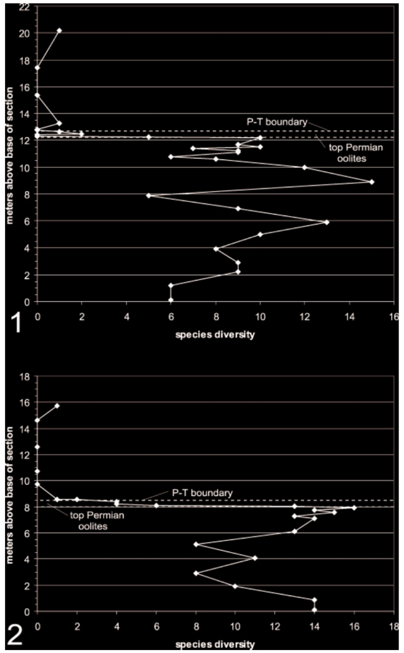
Lucia Angiolini, Laura Carabelli, Aldo Nicora, Sylvie Crasquin-Soleau, Jean Marcoux, Roberto Rettori

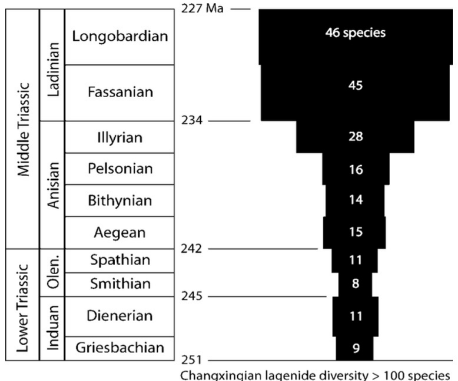


FACIES 36, pp 238-242, 1 Pl., 1Fig., ERLANGEN 1997

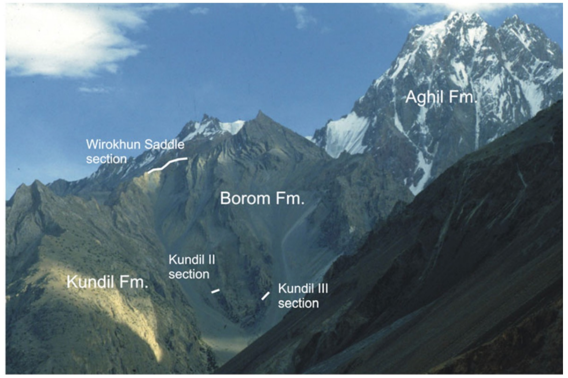
BIOTIC RESPONSE TO MASS EXTINCTION: THE LOWERMOST TRIASSIC MICROBIALITES

Aymon Baud, Lausanne, Simonetta Cirilli, Perugia, Jean Marcoux, Paris





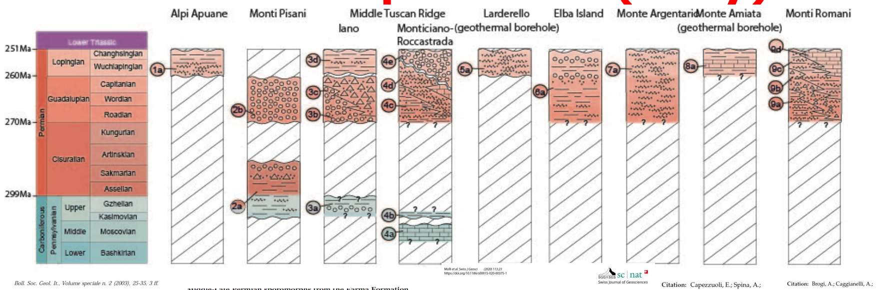
Karakhorum, Pakistan



Refinements in the Upper Permian to Lower Jurassic stratigraphy of Karakorum, Pakistan

Maurizio Gaetani · Alda Nicora · Charles Henderson · Simonetta Cirilli · Luka Gale · Irene Vuolo · Viorel Atudorei

Northern Apennines (Italy)



Stratigraphic correlation of the Upper Palaeozoic-Triassic successions in southern Tuscany, Italy

A. Lazzarotto, M. Aldinucci, S. Cirilli, A. Costantini, F.A. Decandia, E. Pandeli, F. Sandrelli & A. Spina

Stratigraphy and depositional environment of the Mt. Argentario sandstone Fm. (southern Tuscany, Italy)

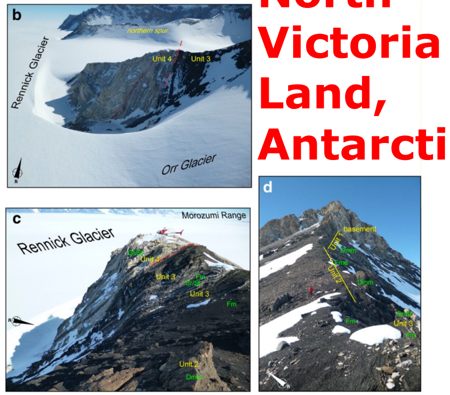
Late Palaeozoic tectonics in Central Mediterranean: a reappraisal

Mid- to late Permian microfloristic evidence in the metamorphic successions of the Northern Apennines: insights for age-constraining and palaeogeographical correlations

Citation: Capezzuoli, E.; Spina, A.; Brogi, A.; Liotta, D.; Bagnoli, G.; Zucchi, M.; Molli, G.; Regoli, R. Reconsidering the Variscan Basement of Southern Tuscany (Inner Northern Apennines). Geosciences 2021, 11, 84. https://doi.org/10.3390/geosciences11020084

Citation: Brogi, A.; Capezzuoli, E.; Liotta, D.; Zucchi, M.; Spina, A.; Capezzuoli, E.; Casini, A.; Buracchi, E. The Gavorrano Monzogranite (Northern Apennines): An Updated Review of Host Rock Protoliths, Thermal Metamorphism and Tectonic Setting. Geosciences 2021, 11, 124. https://doi.org/10.3390/geosciences11030124

North Victoria Land, Antarctic



Sedimentary Geology

Upper Paleozoic glacigenic deposits of Gondwana: Stratigraphy and paleoenvironmental significance of a tillite succession in Northern Victoria Land (Antarctica)

Gianluca Cornamusini, Franco M. Talarico, Simonetta Cirilli, Amalia Spina, Valerio Olivetti, Jusun Woo

Dead Sea, Jordan

RIPS 1895
Rivista Italiana di Paleontologia e Stratigrafia (Research in Paleontology and Stratigraphy) vol. 122(3): 23-40. November

THE PERMIAN -TRIASSIC BOUNDARY, DEAD SEA, JORDAN: TRANSITIONAL ALLUVIAL TO MARINE DEPOSITIONAL SEQUENCES AND BIOSTRATIGRAPHY

JOHN H. POWELL, MICHAEL H. STEPHENSON, ALDA NICORA, ROBERTO RETTORI, LETIZIA M. BORLENGHI & MARIA CRISTINA PERRI

RIPS 1895
Rivista Italiana di Paleontologia e Stratigrafia (Research in Paleontology and Stratigraphy) vol. 125(1): 147-181. March 2019

LOWER TRIASSIC (INDUAN TO OLENEKIAN) CONODONTS, FORAMINIFERA AND BIVALVES FROM THE AL MAMALIH AREA, DEAD SEA, JORDAN: CONSTRAINTS ON THE P-T BOUNDARY

JOHN H. POWELL, ALDA NICORA, MARIA CRISTINA PERRI, ROBERTO RETTORI, RENATO POSENATO, MICHAEL H. STEPHENSON, AHMED MASRI, GHI & VALERIO GENNARI

United Arab Emirates and Oman

Int J Earth Sci (Geol Rundsch)
DOI 10.1007/s00531-007-0194-y

ORIGINAL PAPER

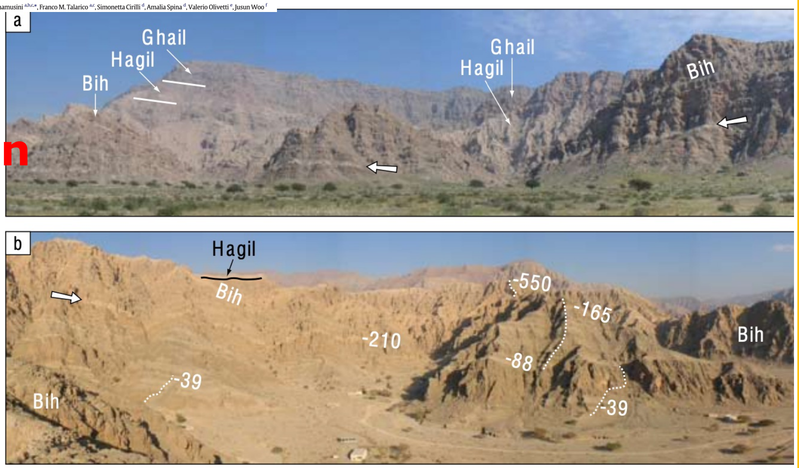
Triassic stratigraphy, facies and evolution of the Arabian shelf in the northern United Arab Emirates

Florian Maurer · Roberto Rettori · Rossana Martini

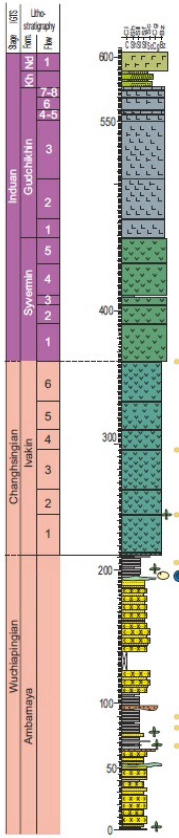
GeoArabia, v. 14, no. 3, 2009, p. 125-158
Gulf PetroLink, Bahrain

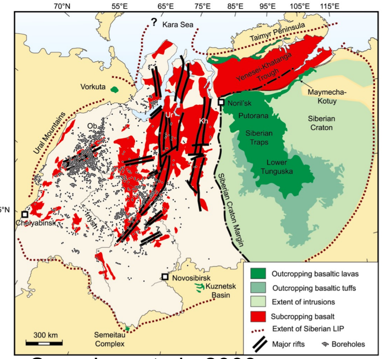
The geology of Khuff outcrop analogues in the Musandam Peninsula, United Arab Emirates and Oman

Florian Maurer, Rossana Martini, Roberto Rettori, Heiko Hillgärtner and Simonetta Cirilli



Siberia





Saunders et al., 2009

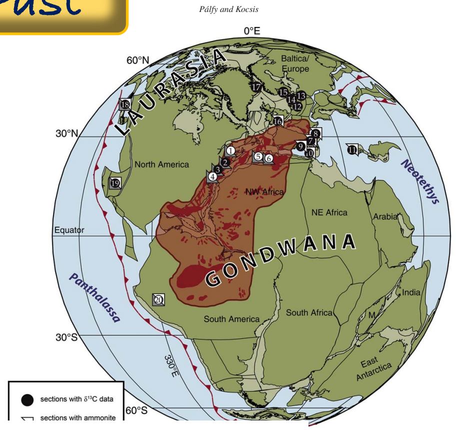
Map of present-day western Siberia and distribution of Permo - Triassic basaltic volcano and sedimentary rocks, dashed line: putative limit of the Siberian Traps LIP

Krasnye Kamni section, Norilsk, Northern Siberia

PT Siberian Traps Project, PI: Spina

Past

End Triassic Exctintion (ETE) (201 My)

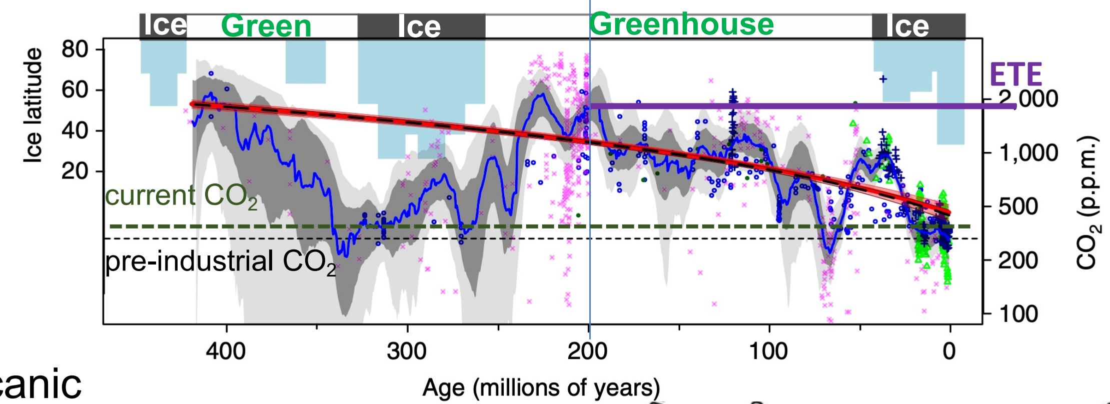


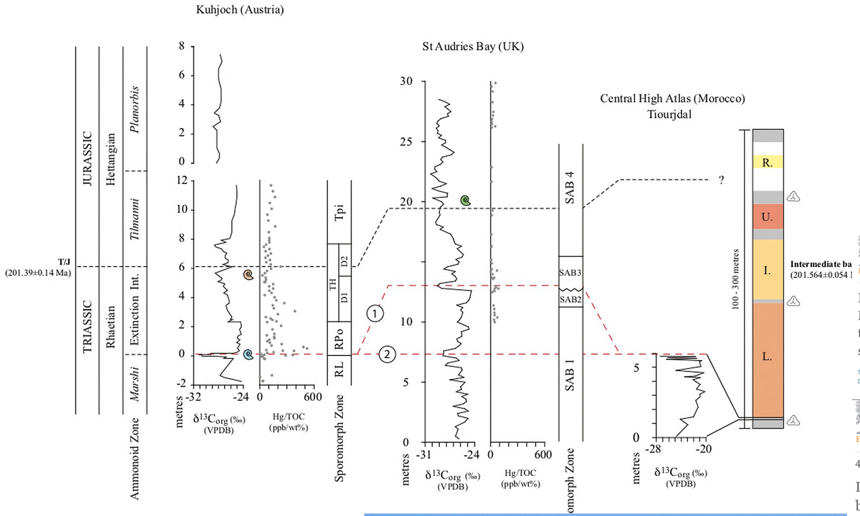
Central Magmatic Province CAMP

total area of >7x10^6 km^2
volume of magma flow: ~2–3 × 10^6 km^3

Short event ~600,000y
rapid release of large amounts of volcanic gases (CO_2 and SO_2) into atmosphere
widespread disruption of the ecosystems

Modified from Foster et al., 2017



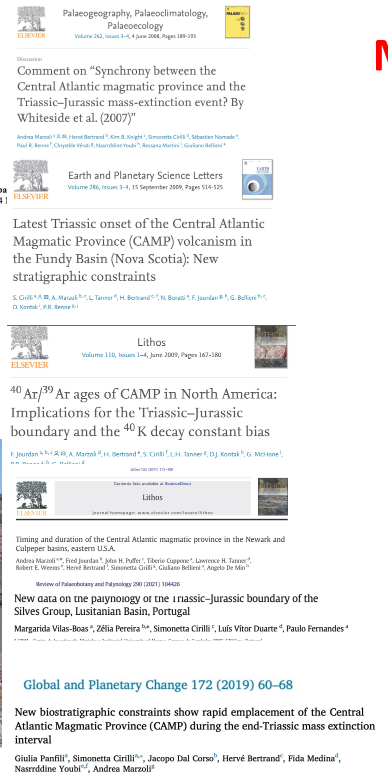


Panfili et al., 2019

Synchrony of the Central Atlantic magmatic province and the Triassic-Jurassic boundary climatic and biotic crisis

Andrea Marzoli; Hervé Bertrand; Kim B. Knight; Simonetta Cirilli; Nicoletta Buratti; Chrystèle Vérati; Sébastien Nomade; Paul R. Renne; Nasrrddine Youbi; Rossana Martini; Karin Allenbach; Ralph Neuwerth; Cédric Rapaille; Louisette Zaninetti; Giuliano Bellieni

Geology (2004) 32 (11): 973–976.



Palaeogeography, Palaeoclimatology, Palaeoecology

Comment on "Synchrony between the Central Atlantic magmatic province and the Triassic–Jurassic mass-extinction event? By Whiteside et al. (2007)"

Earth and Planetary Science Letters

Latest Triassic onset of the Central Atlantic Magmatic Province (CAMP) volcanism in the Fundy Basin (Nova Scotia): New stratigraphic constraints

Lithos

^{40}Ar/^{39}Ar ages of CAMP in North America: Implications for the Triassic–Jurassic boundary and the ^{40}K decay constant bias

Lithos

Timing and duration of the Central Atlantic magmatic province in the Newark and Culpeper basins, eastern U.S.A.

New data on the palynology of the Triassic–Jurassic boundary of the Silves Group, Lusitanian Basin, Portugal

Global and Planetary Change 172 (2019) 60–68

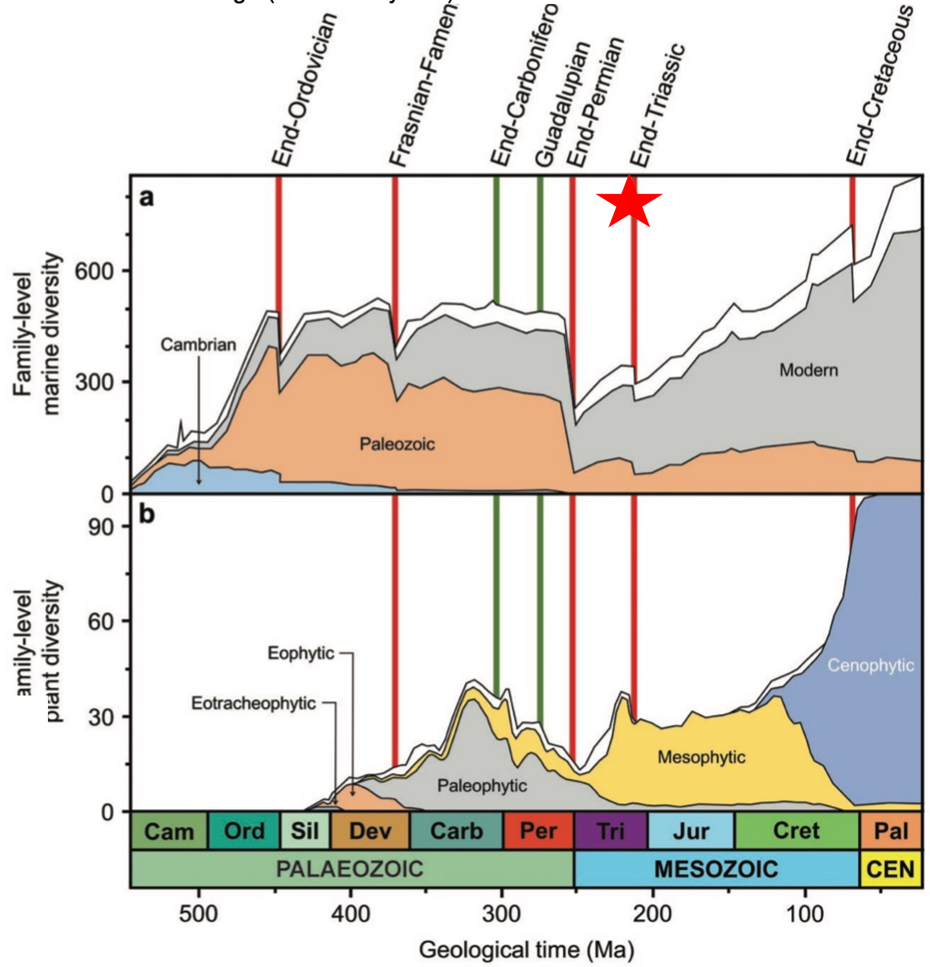
New biostratigraphic constraints show rapid emplacement of the Central Atlantic Magmatic Province (CAMP) during the end-Triassic mass extinction interval

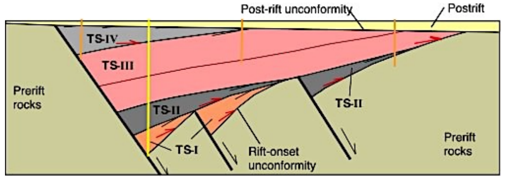
Giulia Panfili, Simonetta Cirilli, Jacopo Dal Corso, Hervé Bertrand, Fida Medina, Nasrrddine Youbi, Andrea Marzoli

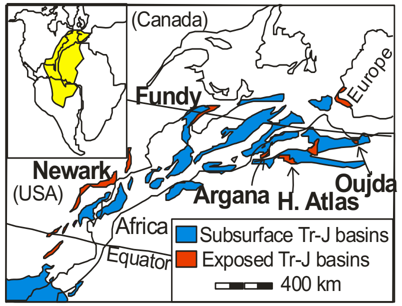
End Triassic Mass Extinction

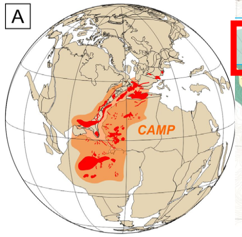
Plants: the great survivors!

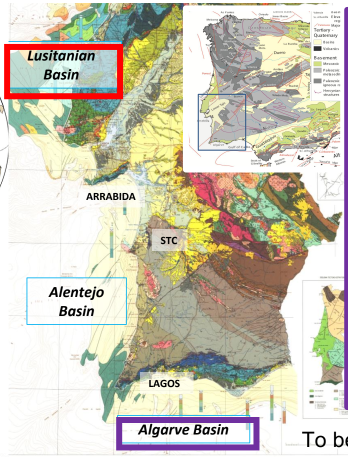
plant diversity increased across the T/J boundary probably due to climatic warming. Very few plant families became extinct







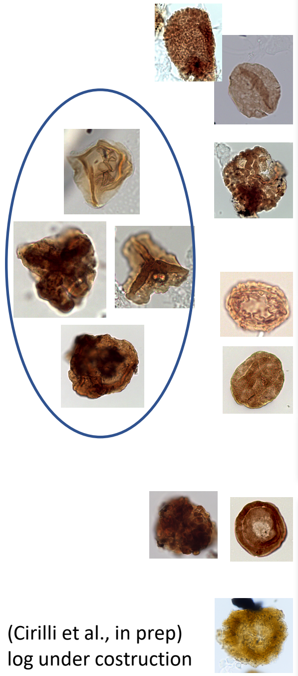


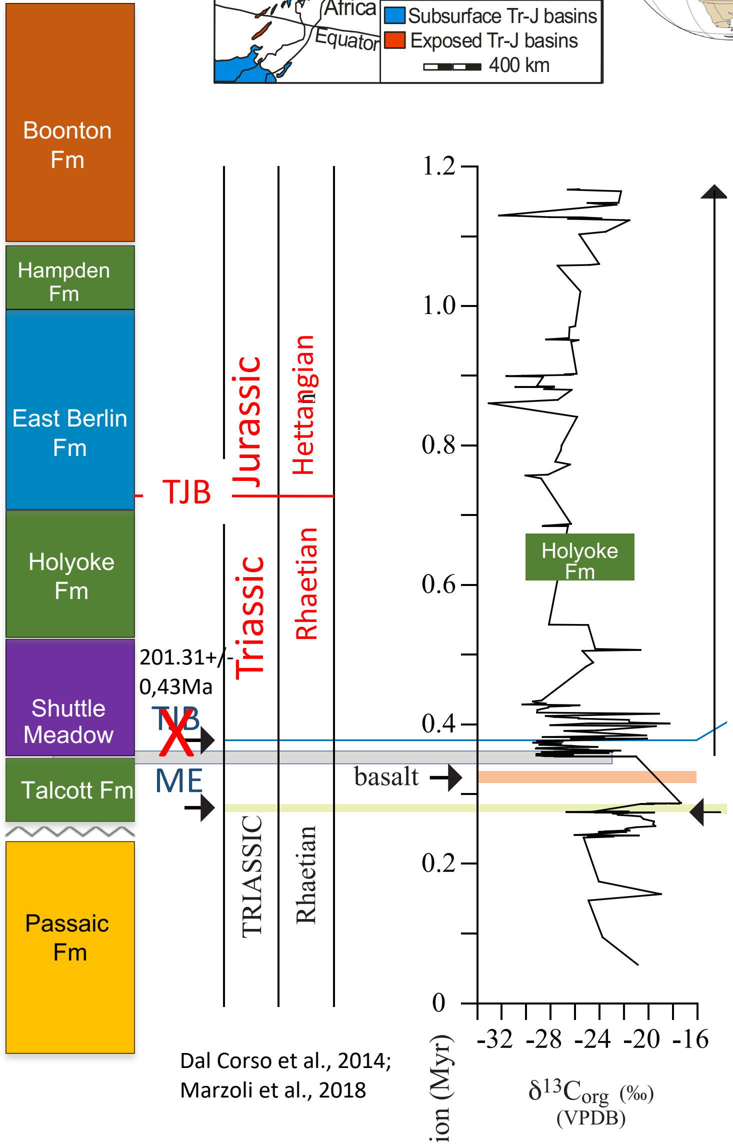


To be done

Newark (ENA)

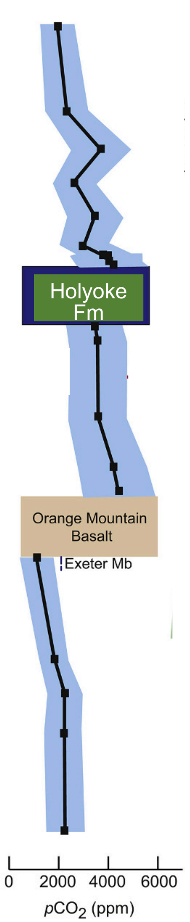
Fluvial lacustrine dep. setting





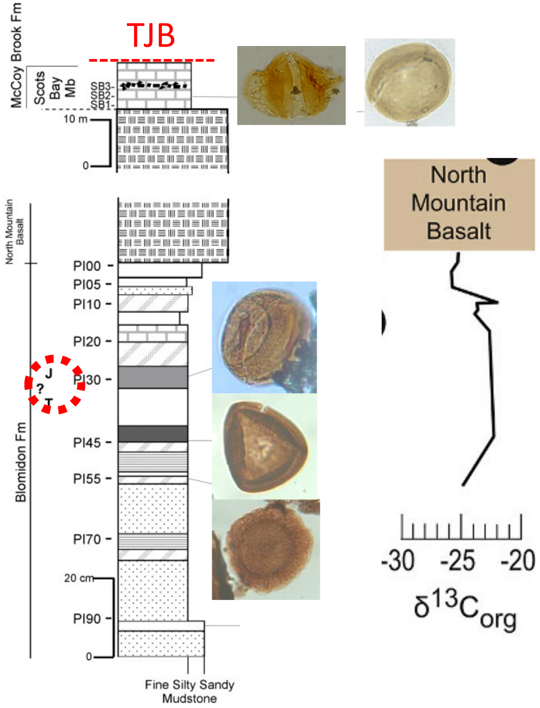
(Cirilli et al., in prep)
log under costruction

Dal Corso et al., 2014; Marzoli et al., 2018



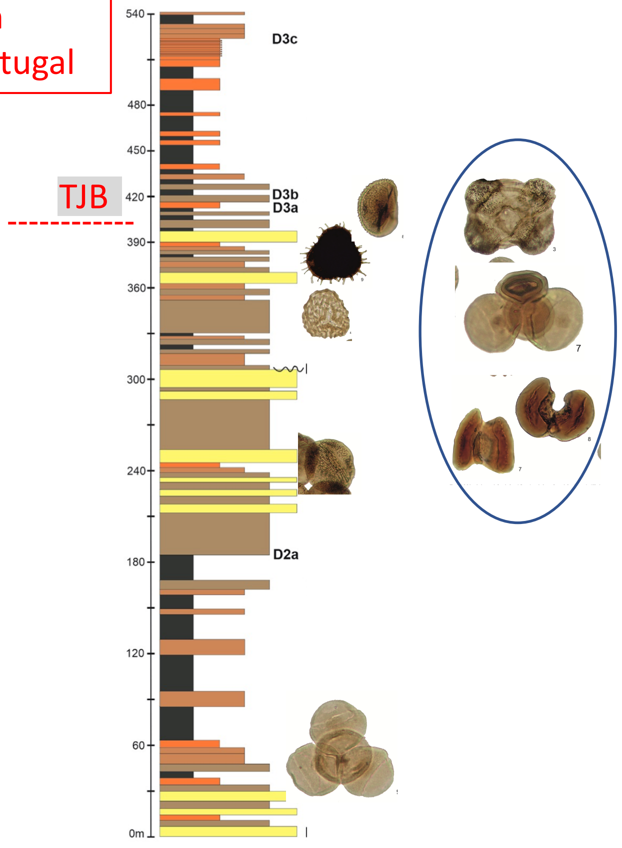
Schaller et al., 2011; 2016

Fundy basin Canada



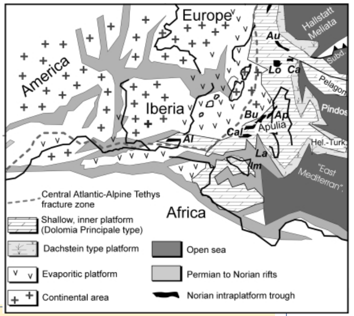
Cirilli et al., 2009; Deenen et al., 2011

Silves Group, Lusitanian Basin, Portugal

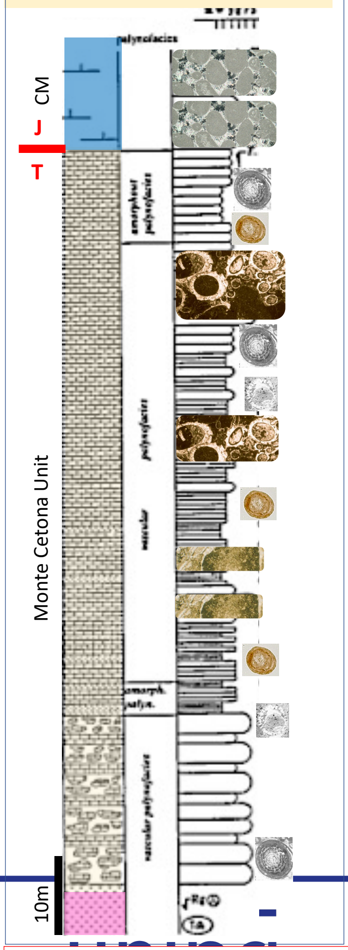


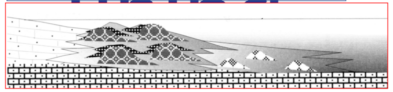
Villa Boas et al., 2021

Past

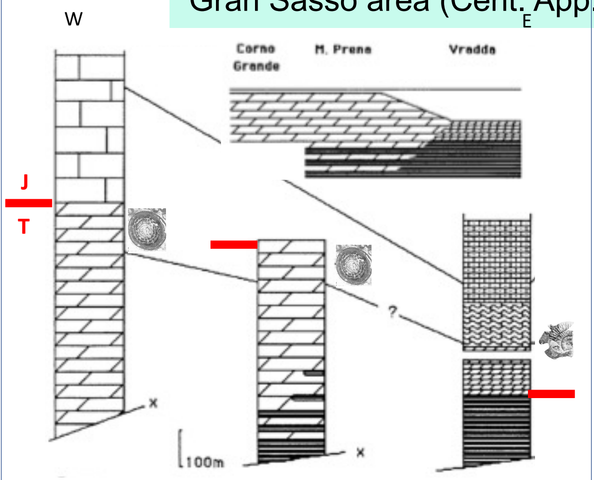


Monte Cetona area (North. App)

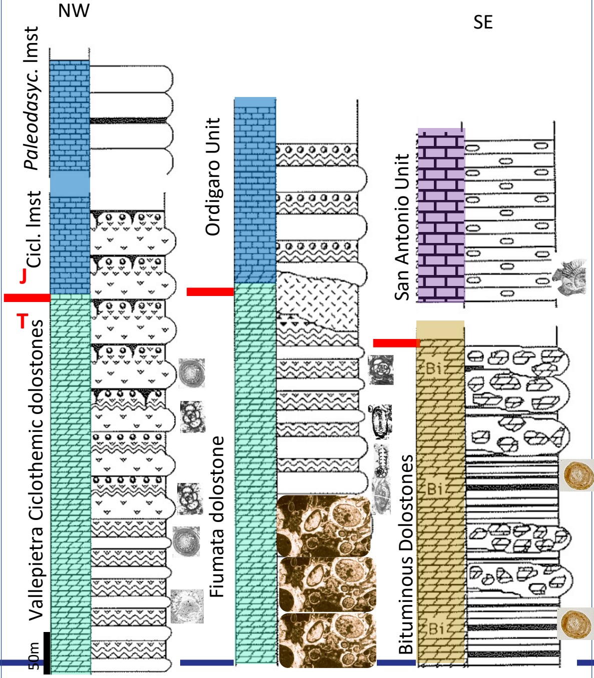


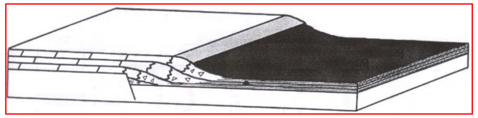


Gran Sasso area (Cent. App.)

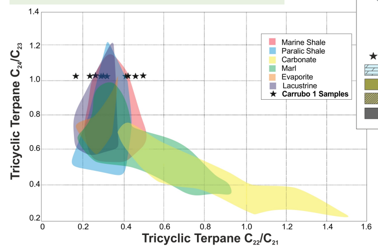


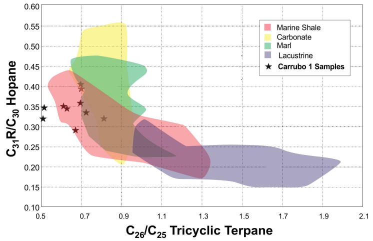
Simbruini Mts (cent. App.)

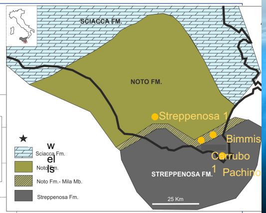


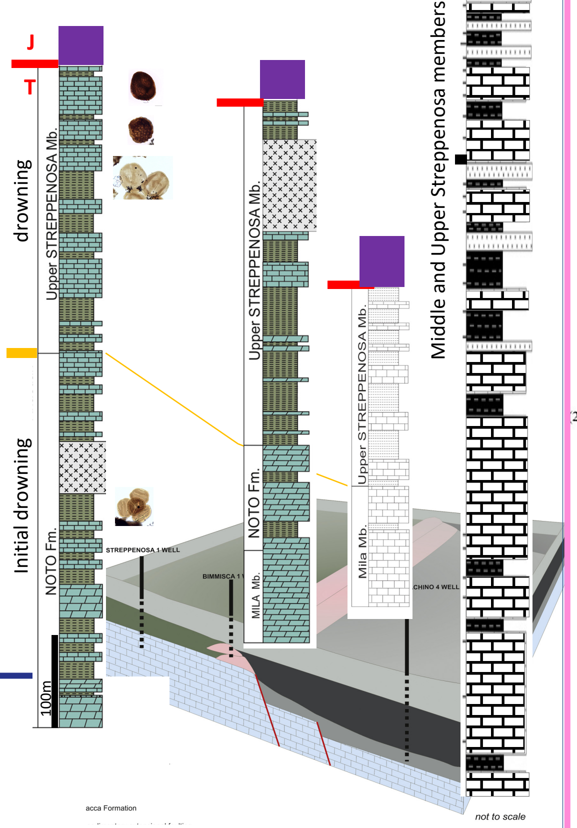


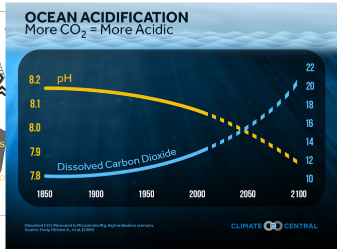
Hyblean Plateau Sicily

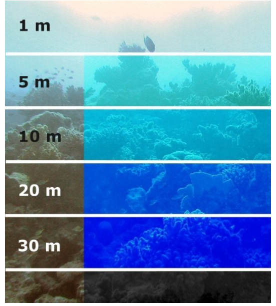










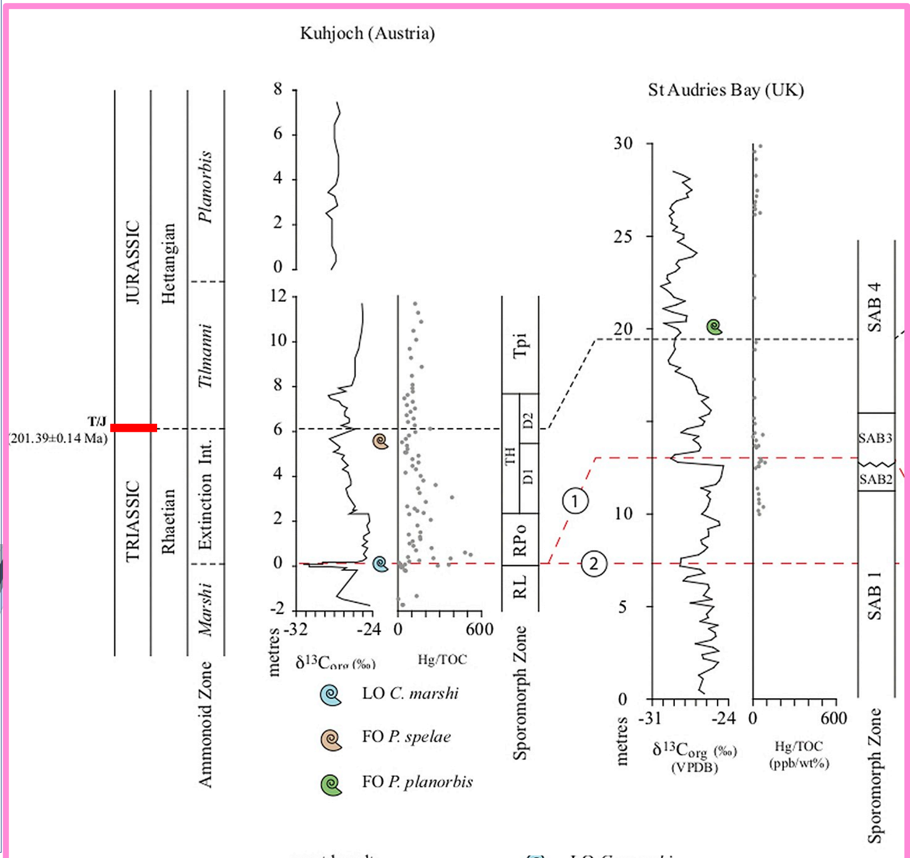


oceanic water acidification and anoxia presence of PZE: anaerobic conditions in relative shallow and confined basins in the deepest part of the basin and in the marginal areas

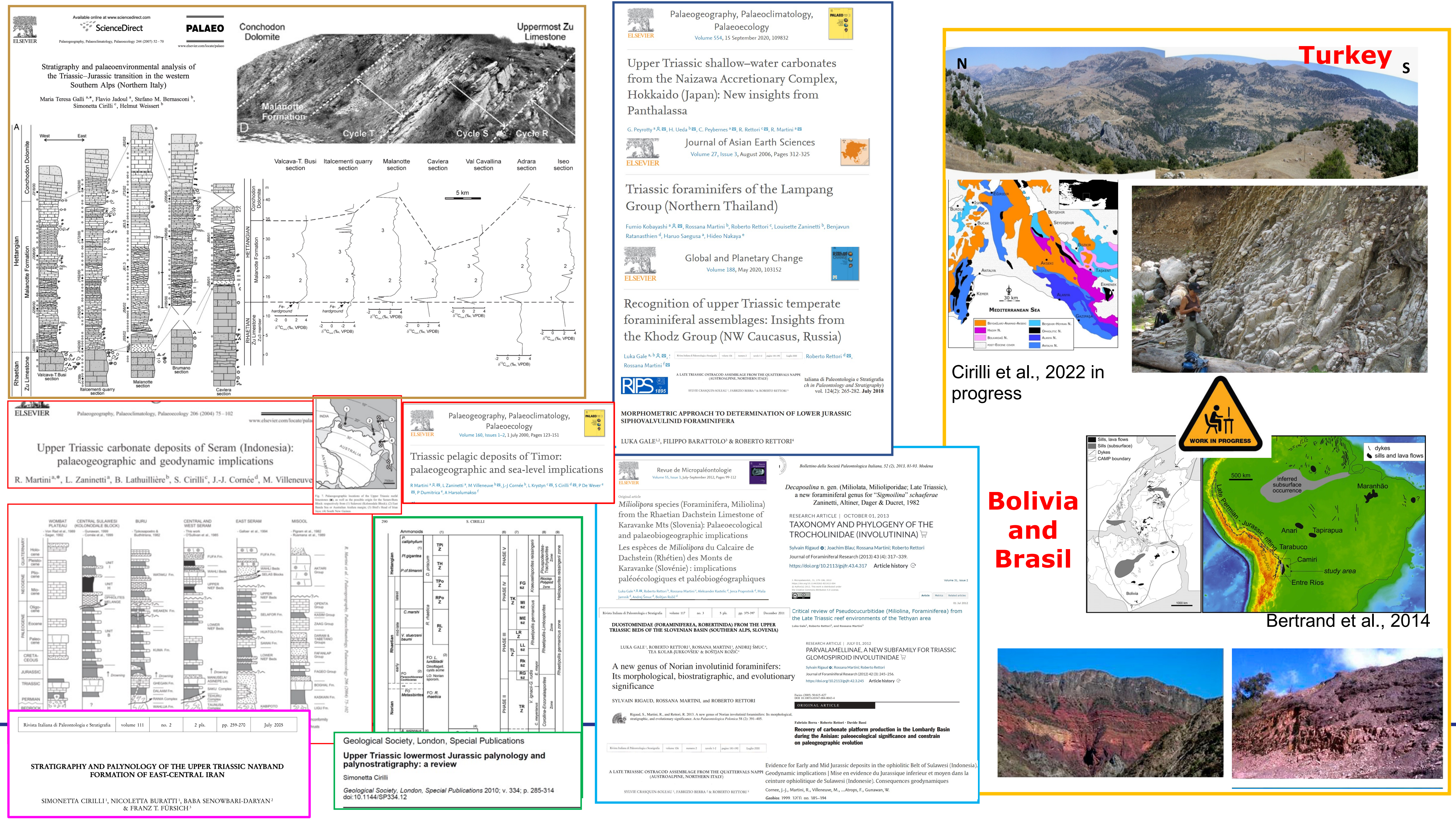
Late Triassic

The low oxygen level prevented the colonization of the marginal area by sphinctozoan/coral communities and allowed the development of microbial and serpulid dominated reefs.

During **Early Jurassic**, at least at the temperate belts, the shallow marine settings are characterized by an extensive carbonate deposition not only of biogenic origin but also as abiogenic carbonate precipitation.



Cirilli et al., 1994; Cirilli, 1997; Cirilli 1999; Cirilli et al in prep



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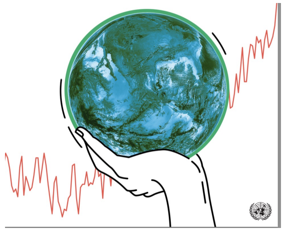
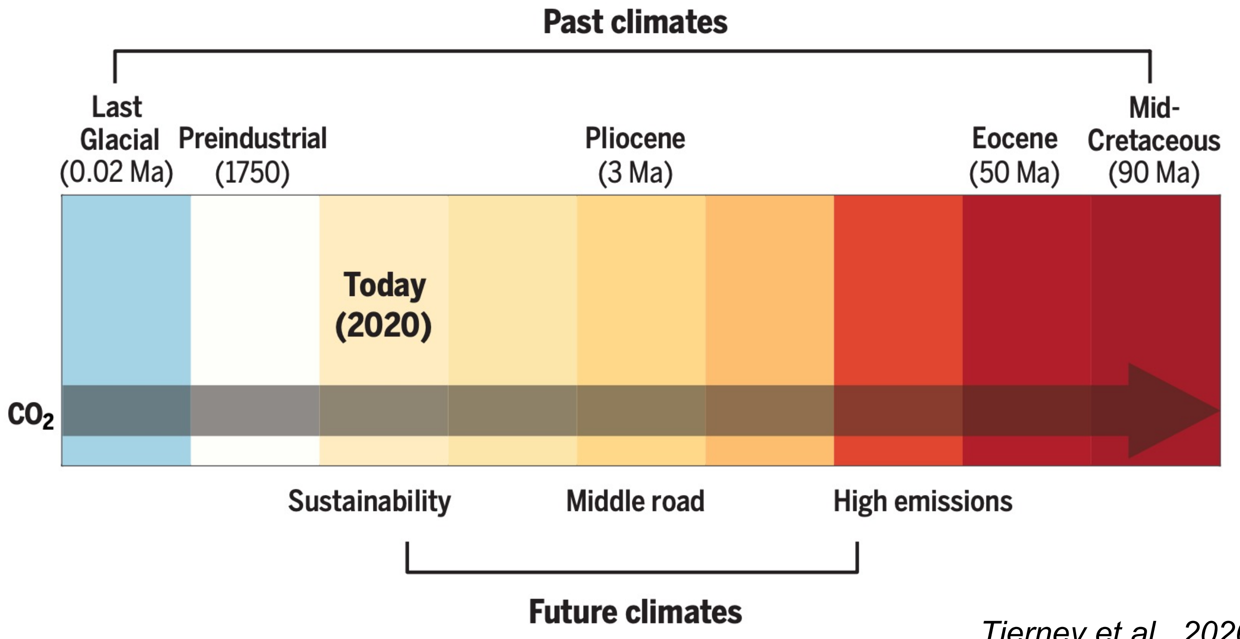
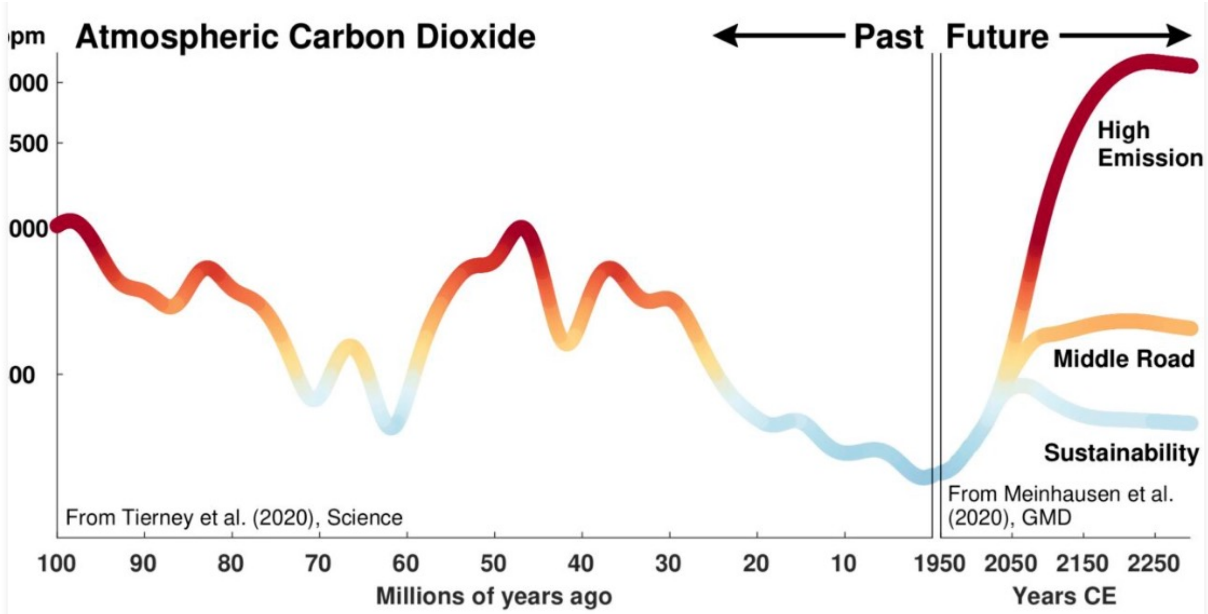
ELSEVIER
Palaeogeography, Palaeoclimatology, Palaeoecology 244 (2007) 52–70
Stratigraphy and palaeoenvironmental analysis of the Triassic–Jurassic transition in the western Southern Alps (Northern Italy)
Maria Teresa Galli, Flavio Jadoul, Stefano M. Bernasconi, Simonetta Cirilli, Helmut Weissert
Conchodon Dolomite
Uppermost Zu Limestone
Malanotte Formation
Cycle T
Cycle S
Cycle R
Valcava-T. Busi section
Italcementi quarry section
Malanotte section
Cavlera section
Val Cavallina section
Adrara section
Iseo section
5 km
Hettangian
Rhaetian
Conchodon Dolomite
Malanotte Formation
Zu Limestone
Fe-hardground
Palaeogeography, Palaeoclimatology, Palaeoecology
Volume 554, 15 September 2020, 109832
Upper Triassic shallow–water carbonates from the Naizawa Accretionary Complex, Hokkaido (Japan): New insights from Panthalassa
G. Peyrotty, H. Ueda, C. Peybernes, R. Rettori, R. Martini
Journal of Asian Earth Sciences
Volume 27, Issue 3, August 2006, Pages 312-325
Triassic foraminifers of the Lampang Group (Northern Thailand)
Fumio Kobayashi, Rossana Martini, Roberto Rettori, Louisette Zaninetti, Benjavun Ratanasthien, Haruo Saegusa, Hideo Nakaya
Global and Planetary Change
Volume 188, May 2020, 103152
Recognition of upper Triassic temperate foraminiferal assemblages: Insights from the Khodz Group (NW Caucasus, Russia)
Luka Gale, Roberto Rettori, Rossana Martini
Rivista Italiana di Paleontologia e Stratigrafia vol. 124(2): 265-282. July 2018
MORPHOMETRIC APPROACH TO DETERMINATION OF LOWER JURASSIC SIPHOVALVULINID FORAMINIFERA
LUKA GALE, FILIPPO BARATTOLO & ROBERTO RETTORI
Turkey
N
S
MEDITERRANEAN SEA
30 km
Cirilli et al., 2022 in progress
WORK IN PROGRESS
Palaeogeography, Palaeoclimatology, Palaeoecology 206 (2004) 75–102
Upper Triassic carbonate deposits of Seram (Indonesia): palaeogeographic and geodynamic implications
R. Martini, L. Zaninetti, B. Lathuillière, S. Cirilli, J.-J. Cornée, M. Villeneuve
AUSTRALIA
ANTARCTICA
INDIA
Palaeogeography, Palaeoclimatology, Palaeoecology
Volume 160, Issues 1–2, 1 July 2000, Pages 123-151
Triassic pelagic deposits of Timor: palaeogeographic and sea-level implications
R Martini, L Zaninetti, M Villeneuve, J-J Cornée, L Krystyn, S Cirilli, P De Wever, P Dumitrica, A Harsolumakso
Revue de Micropaléontologie
Volume 55, Issue 3, July-September 2012, Pages 99-112
Miliolipora species (Foraminifera, Miliolina) from the Rhaetian Dachstein Limestone of Karavanke Mts (Slovenia): Palaeoecological and palaeobiogeographical implications
Les espèces de Miliolipora du Calcaire de Dachstein (Rhétien) des Monts de Karavanke (Slovénie) : implications paléoécologiques et paléobiogéographiques
Bollettino della Società Paleontologica Italiana, 52 (2), 2013, 81-93. Modena
Decapoalina n. gen. (Miliolata, Milioliporidae; Late Triassic), a new foraminiferal genus for "Sigmoilina" schaeferae Zaninetti, Altiner, Dager & Ducret, 1982
RESEARCH ARTICLE | OCTOBER 01, 2013
TAXONOMY AND PHYLOGENY OF THE TROCHOLINIDAE (INVOLUTININA)
Sylvain Rigaud; Joachim Blau; Rossana Martini; Roberto Rettori
Journal of Foraminiferal Research (2013) 43 (4): 317–339.
https://doi.org/10.2113/gsjfr.43.4.317
Critical review of Pseudocucurbitidae (Miliolina, Foraminiferea) from the Late Triassic reef environments of the Tethyan area
DUOSTOMINIDAE (FORAMINIFEREA, ROBERTINIDA) FROM THE UPPER TRIASSIC BEDS OF THE SLOVENIAN BASIN (SOUTHERN ALPS, SLOVENIA)
RESEARCH ARTICLE | JULY 01, 2012
PARVALAMELLINAE, A NEW SUBFAMILY FOR TRIASSIC GLOMOSPIROID INVOLUTINIDAE
Sylvain Rigaud; Rossana Martini; Roberto Rettori
Journal of Foraminiferal Research (2012) 42 (3): 245–256.
A new genus of Norian involutinid foraminifers: Its morphological, biostratigraphic, and evolutionary significance
SYLVAIN RIGAUD, ROSSANA MARTINI, and ROBERTO RETTORI
ORIGINAL ARTICLE
Recovery of carbonate platform production in the Lombardy Basin during the Anisian: paleoecological significance and constrain on paleogeographic evolution
A LATE TRIASSIC OSTRACOD ASSEMBLAGE FROM THE QUATTERVALS NAPPE (AUSTROALPINE, NORTHERN ITALY)
SYLVIE CRASQUIN-SOLEAU, FABRIZIO BERRA & ROBERTO RETTORI
Evidence for Early and Mid Jurassic deposits in the ophiolitic Belt of Sulawesi (Indonesia). Geodynamic implications | Mise en evidence du Jurassique inferieur et moyen dans la ceinture ophiolitique de Sulawesi (Indonesie). Consequences geodynamiques
Cornee, J.-J., Martini, R., Villeneuve, M., ...Atrops, F., Gunawan, W.
Geobios 1999, 32(3), pp. 385–394
Bolivia and Brasil
Sills, lava flows
Sills (subsurface)
Dykes
CAMP boundary
dykes
sills and lava flows
500 km
inferred subsurface occurrence
Maranhão
Anari
Tapirapua
Tarabuco
Camiri
Entre Rios
study area
Late Permian – Jurassic rifting
Bertrand et al., 2014
WOMBAT PLATEAU
CENTRAL SULAWESI (KOLONODALE BLOCK)
BURU
CENTRAL AND WEST SERAM
EAST SERAM
MISOOL
S. CIRILLI
Ammonoids
Hettangian
Rhaetian
Norian
Rivista Italiana di Paleontologia e Stratigrafia volume 111 no. 2 2 pls. pp. 259-270 July 2005
STRATIGRAPHY AND PALYNOLOGY OF THE UPPER TRIASSIC NAYBAND FORMATION OF EAST-CENTRAL IRAN
SIMONETTA CIRILLI, NICOLETTA BURATTI, BABA SENOWBARI-DARYAN & FRANZ T. FÜRSICH
Geological Society, London, Special Publications
Upper Triassic lowermost Jurassic palynology and palynostratigraphy: a review
Simonetta Cirilli
Geological Society, London, Special Publications 2010; v. 334; p. 285-314
doi:10.1144/SP334.12



Past climates provide the only opportunity to observe how the Earth system responds to high carbon dioxide, underlining a fundamental role for paleoclimatology in constraining future climate change



Tierney et al., 2020

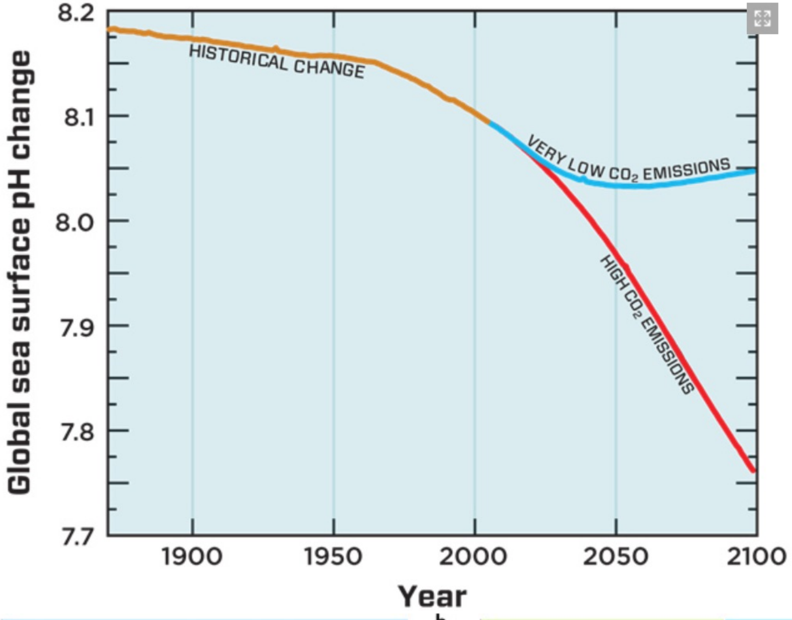


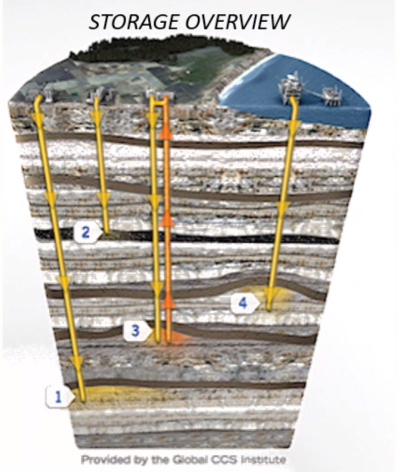
Understanding of the Earth system at time scales longer than human observations has became imperative, because anthropogenic activities are likely to telescope by order of magnitude the rates of climatic change that usually result from geologic (= natural) processes.

Future

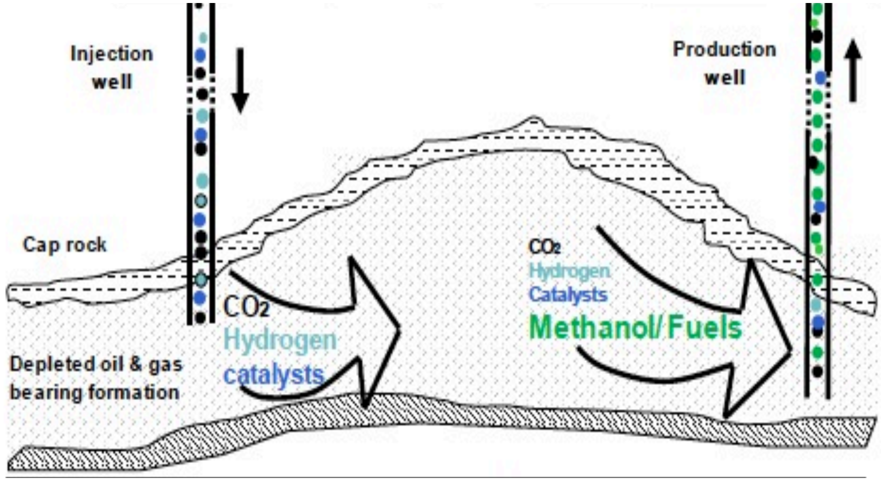
CO_2 Capture, Underground Storage, Utilization

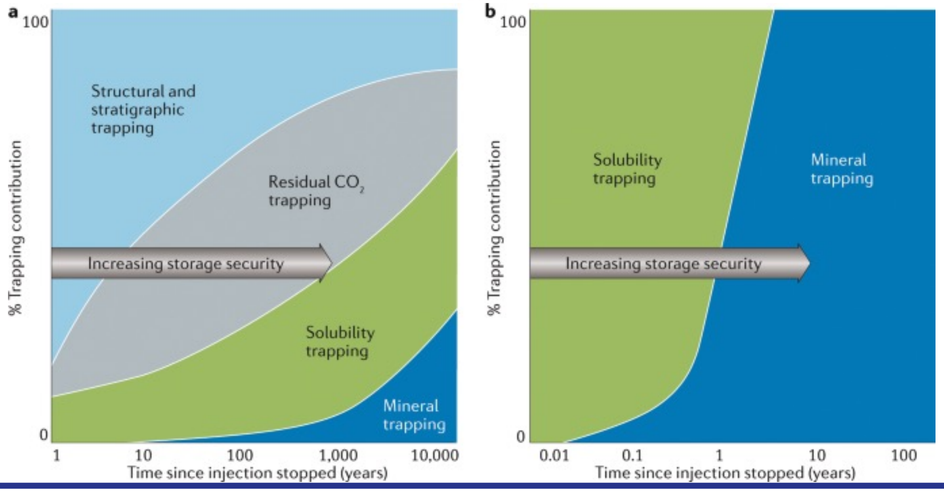
GeoFac *project*
ERC Synergy Grant
In progress



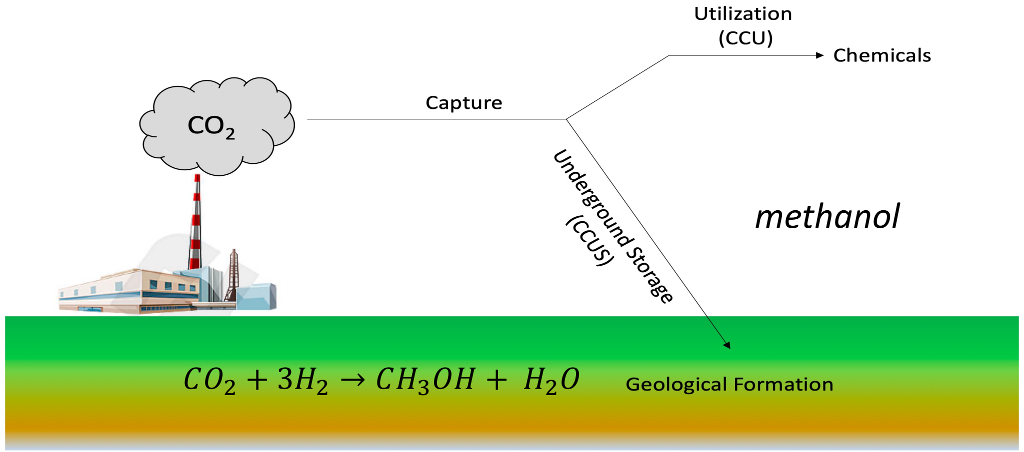


1. *Saline Formation*
2. *Injection into deep unmineable coal seams or ECBM*
3. *Use of CO2 in enhanced oil recovery*
4. *Depleted oil and gas reservoir*





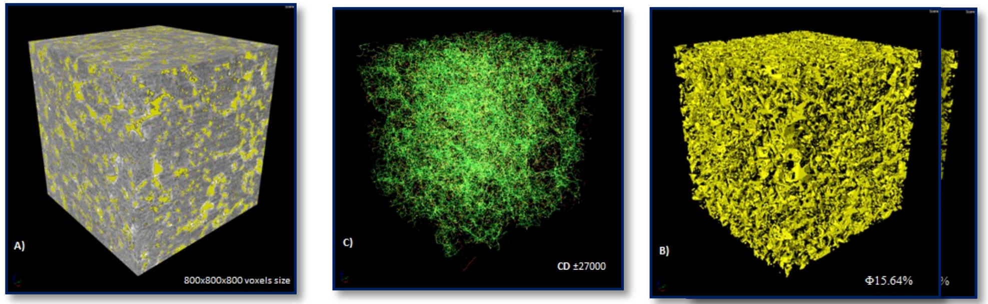
Sedimentary reservoirs enable to host injected CO_2



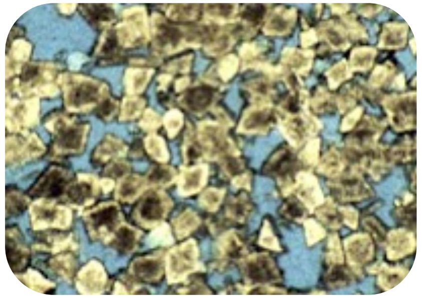
Future

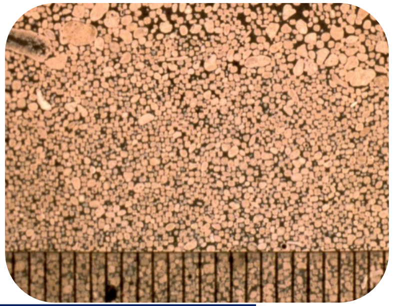
Sedimentologic and Structural analyses

X-ray Computed Tomography (XRCT) analysis.

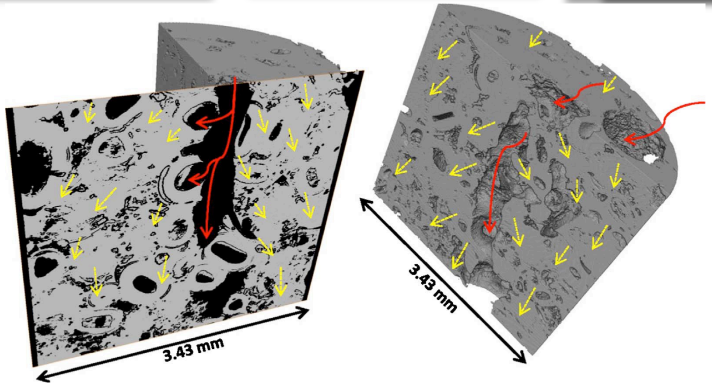


Facies and petrographic analyses

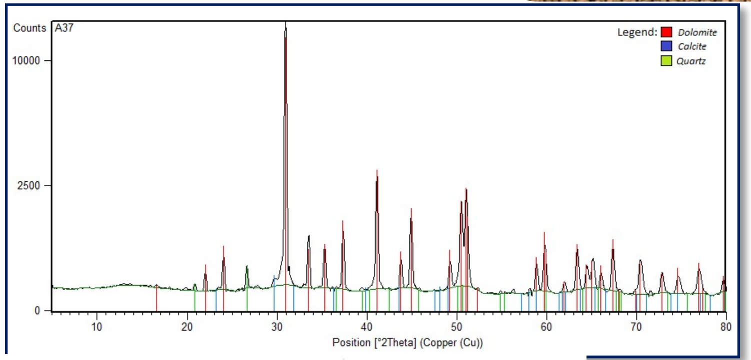




X-ray phase-contrast microtomography (μ-CT)

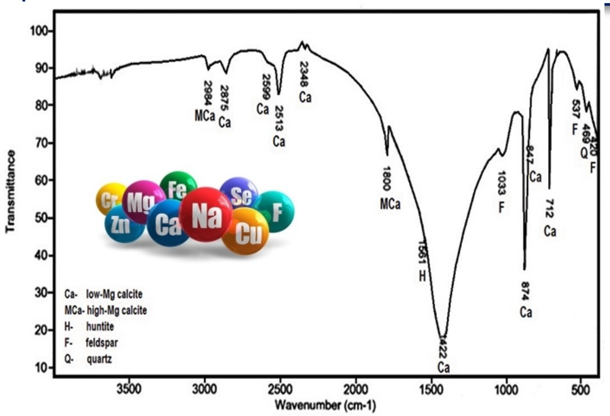


X-ray Powder Diffraction (XRPD) analysis.

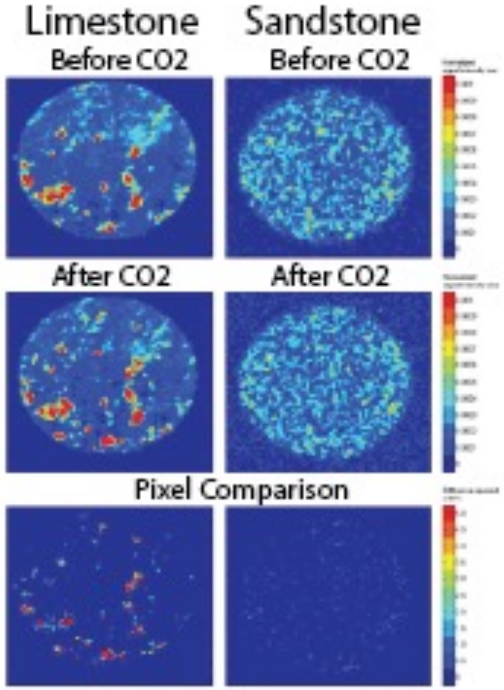


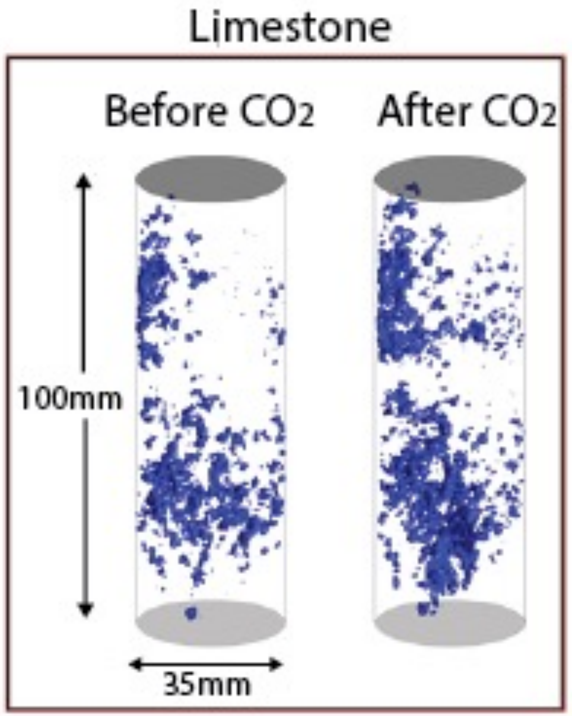
Chemical and mineralogical analyses

✓ Catalysts elements



Experimental phase to understand the physics and chemical role of the rock within the catalytic process.





Chimica, Biologia e Biotecnologie

Filosofia, scienze sociali, umane e della formazione

Ingegneria Civile ed Ambientale

Scienze Agrarie, Alimentari e Ambient.

Economia

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Azioni di Ateneo

Linea azione 5: Clima, energia e mobilità

- **WP 5.2** — *Cambiamenti climatici: consapevolezza impatto sociale, modelli scientifici e soluzioni tecnologiche*
- **WP 5.1** — *Infrastrutture, sistemi energetici e produttivi a basso impatto ambientale*

Linea azione 2: Cultura, creatività e società inclusive

- **WP 2.2** — *Tecniche e strategie di comunicazione della conoscenza*
- **WP 2.3** — *Individuo e società: benessere e inclusione*