junt@sadistância

Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia

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Instituto de Ciência e Tecnologia
Universidade Federal dos Vales do Jequitinhonha e Mucuri
Diamantina, MG

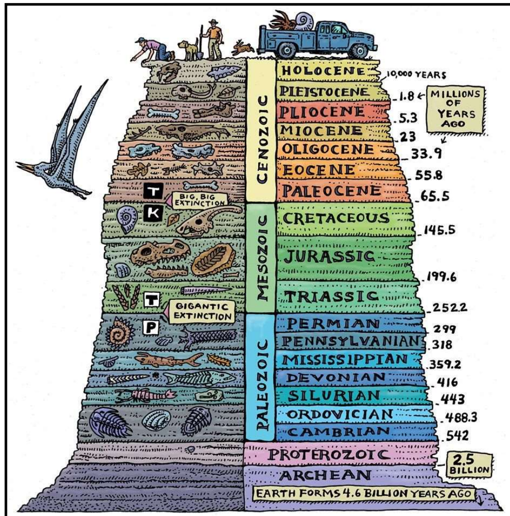
1

Fósseis do Pré-Cambriano

Astrobiologia

Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia

2

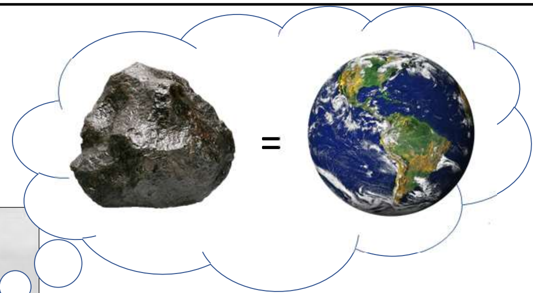


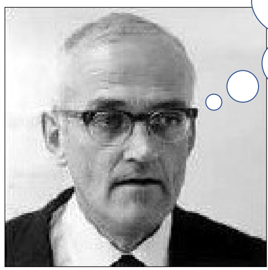
Tempo Geológico

Tempo de existência do planeta Terra

4.55 bilhões de anos (Ga)

3



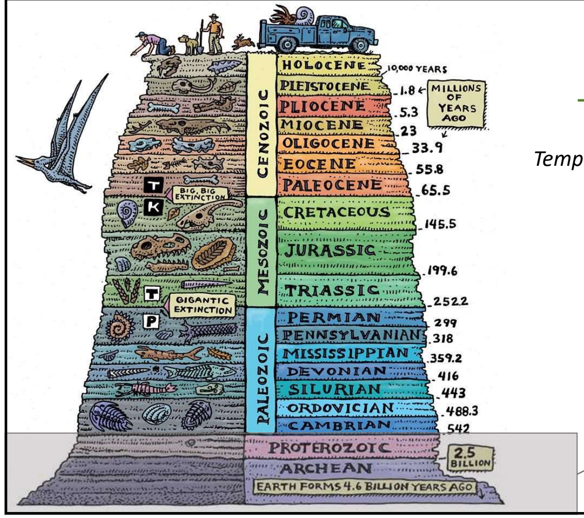


Clair Cameron Patterson

Método $^{207}Pb/^{204}Pb$ e $^{206}Pb/^{204}Pb$

4,55 ± 0,07 Ga

4



Tempo Geológico

Tempo de existência do planeta Terra

4.55 bilhões de anos (Ga)

Pré-Cambriano =
Criptozoico, Azoico ou Pré-Fanerozoico

88% da história do planeta

5

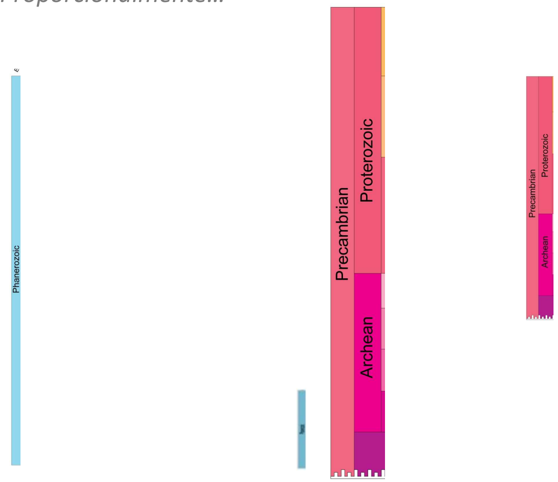
INTERNATIONAL CHRONOSTRATIGRAPHIC CHART

IUGS www.stratigraphy.org International Commission on Stratigraphy

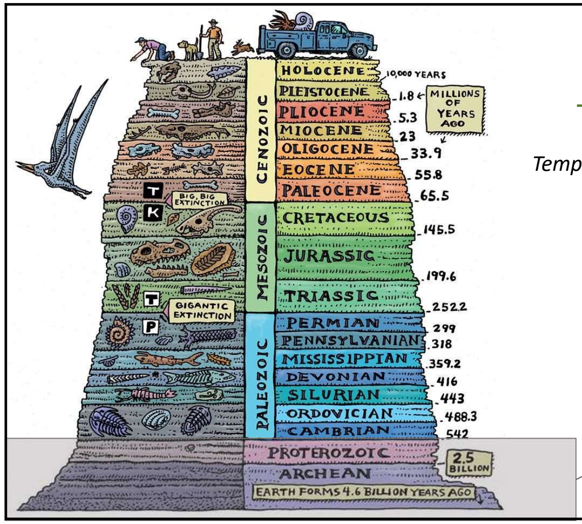
http://www.stratigraphy.org/index.php/ics-chart-timescale

6

Proporcionalmente...



7



Tempo Geológico

Tempo de existência do planeta Terra

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Criptozoico, Azoico ou Pré-Fanerozoico

88% da história do planeta

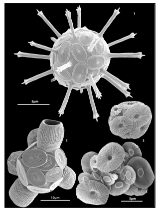
8

Fósseis

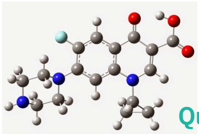

Paleovertebrados


Paleoinvertebrados


Paleobotânica

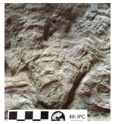

Micropaleontologia

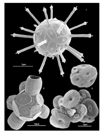
Paleoicnologia



Quimiofósseis

9

Fósseis do Pré-Cambriano


"Icnofósseis"
- Microbialitos
- *Microbially Induced Sedimentary Structures* (MISS)


Microfósseis
- Associados a microbialitos
- Formas livres planctônicas ou bentônicas
- Eucariontes e procariontes

10

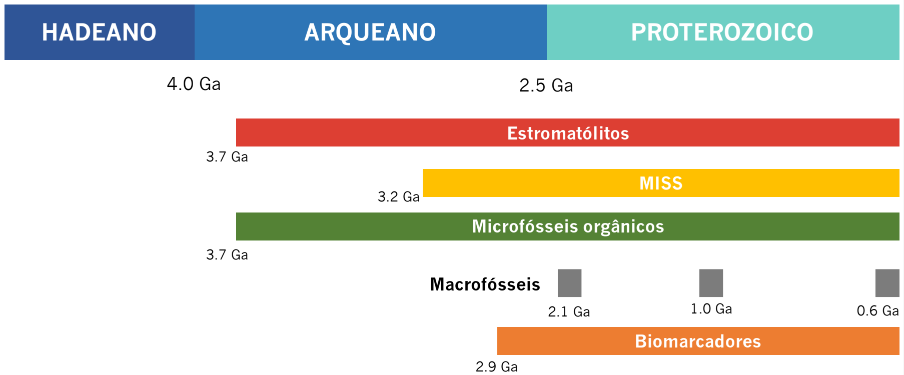
Fósseis do Pré-Cambriano


Macrofósseis
- Metazoários
- Rangeomorfos e Erniettomorfos
- Algas
- Incertae Sedis


Quimiofósseis
(Biomarcadores)
- Matéria orgânica
- Isótopos

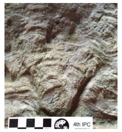
11

Fósseis do Pré-Cambriano

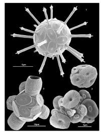


12

Fósseis do Pré-Cambriano de interesse

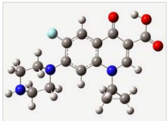


Estromatólitos
MISS



Microfósseis

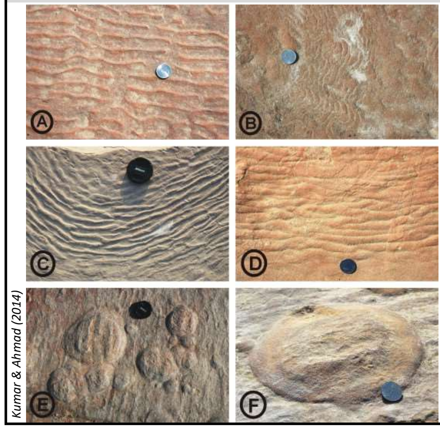
Metazoários
Rangeomorfos
Erniettomorfos
Algas
Incertae Sedis



Biomarcadores

13

Microbially Induced Sedimentary Structures



Interação micro-organismos e sedimentos

Registro de vida em ambientes siliciclásticos

17 tipos de MISS

2.9 Ga até Recente

14

Microbially Induced Sedimentary Structures

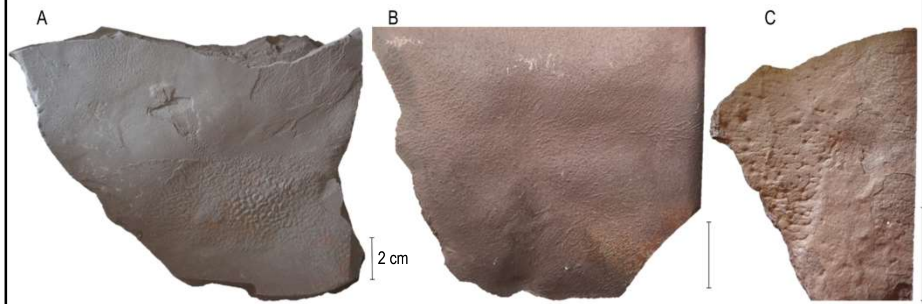
Noffke (2009)

Critérios de Biogenicidade:

1. Ocorrer em rochas sedimentares ou com baixo grau de metamorfismo
2. Ocorrer em sequências transgressivas
3. Ocorrer na "fácies" microbiótica
4. Distribuição que reflita padrões hidráulicos na mesma área
5. Geometria e tamanho sejam semelhantes as de formas modernas
6. Microtexturas típicas de esteiras microbianas ou biofilmes

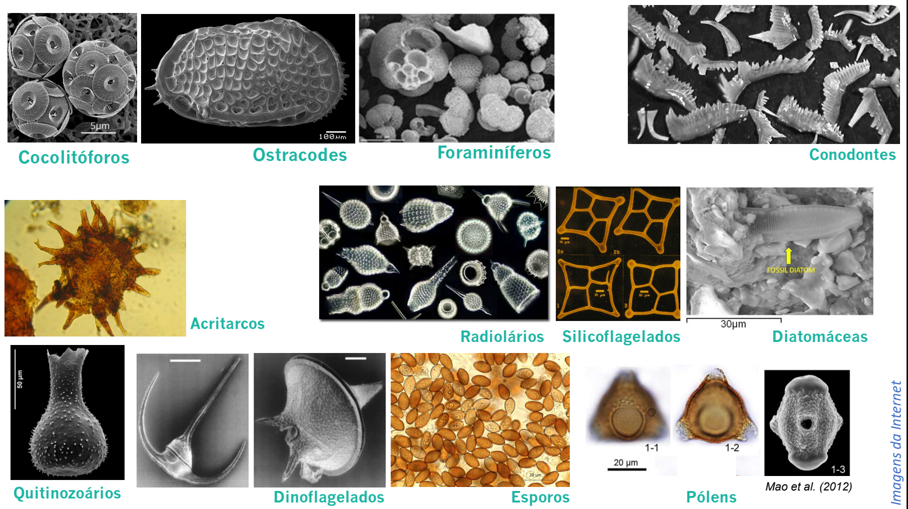
15

Microbially Induced Sedimentary Structures



MISS – Grupo Bambuí
Ediacariano – Cambriano, Minas Gerais

16



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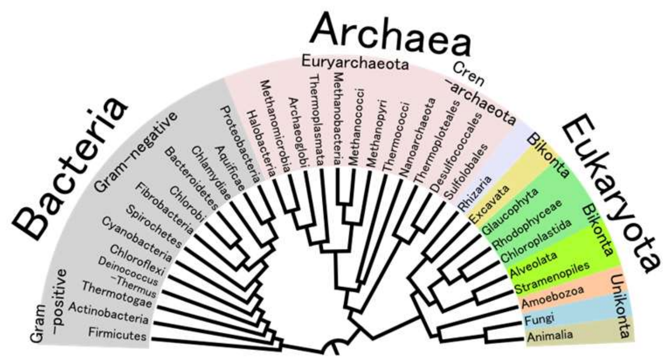
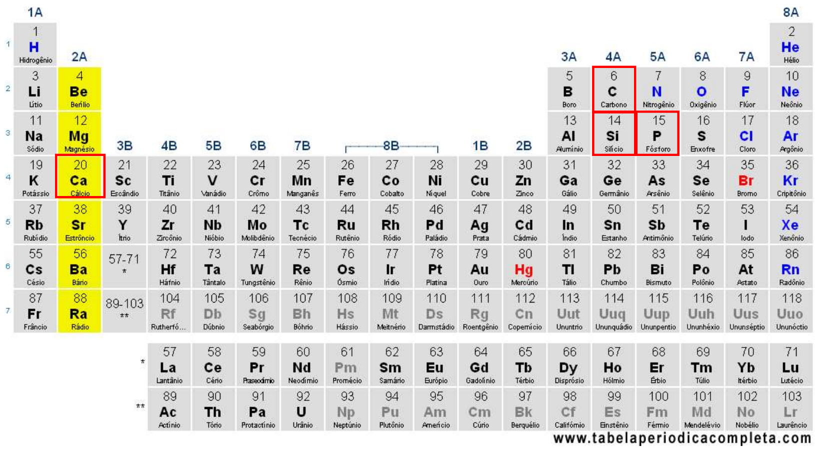
Como classificá-los?



Diferentes grupos

18

Haq & Boersma (1994)



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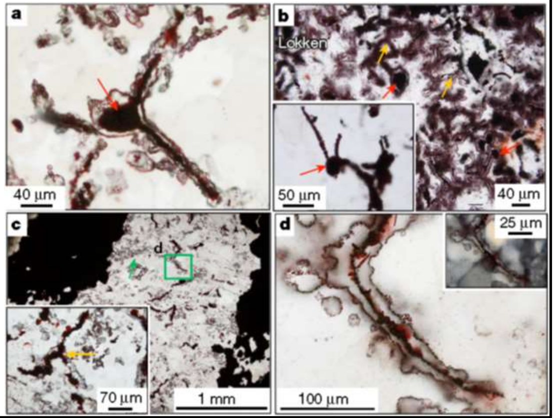
Formas mais antigas de vida

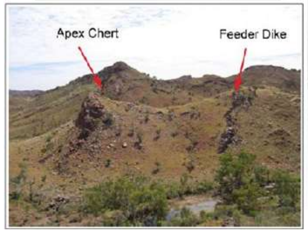
3.7 Ga
Quebec, Canadá

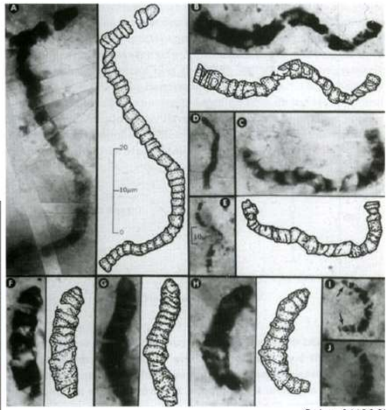
Dood et al. (2017)



20

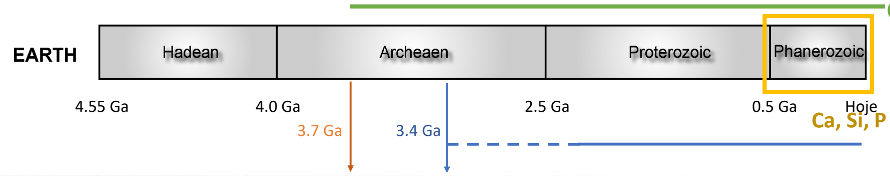
Formas mais antigas de vida

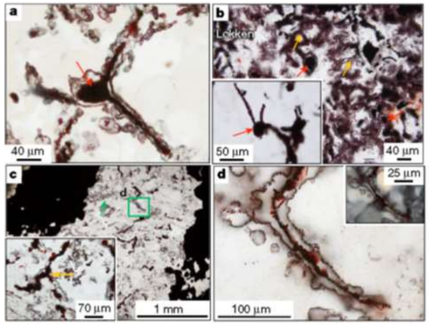


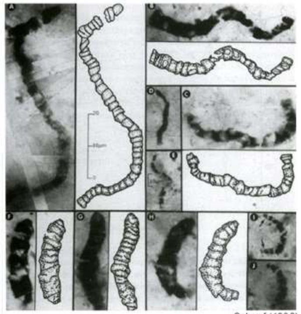


Schopf (1993)

21



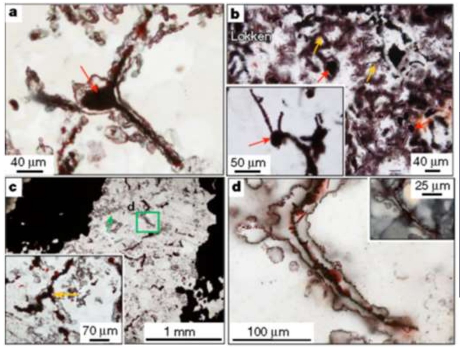


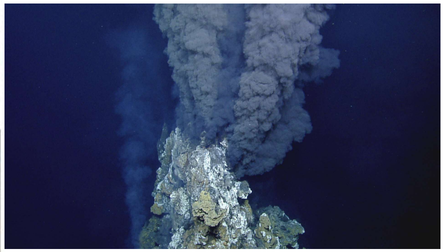


Schopf (1993)

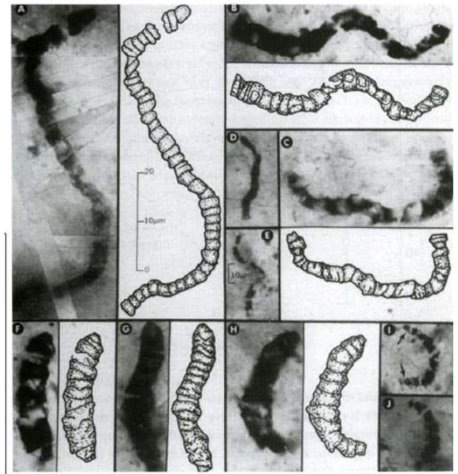
22

Qual a afinidade biológica? Análogos modernos





23



Schopf (1993)

Microfósseis de Apex Chert, W Austrália

3.4 Ga

Onze táxons identificados

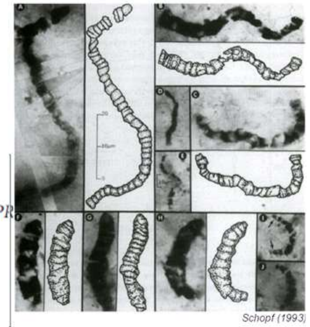
Afinidade com cianobactérias

24

Questioning the evidence for Earth's oldest fossils

Martin D. Brasier*, Owen R. Green*, Andrew P. Jephcoat*, Annette K. Kleppe*, Martin J. Van Kranendonk†, John F. Lindsay‡, Andrew Steele§ & Nathalie V. Grassineau‖

** Earth Sciences Department, University of Oxford, Parks Road, Oxford OX1 3PR, UK*
† Geological Survey of Western Australia, 100 Plain Street, East Perth, Western Australia, 6004, Australia
‡ Research School of Earth Sciences, Australian National University, Canberra ACT 0200, Australia
§ School of Earth, Environmental and Physical Sciences, University of Portsmouth, Burnaby Road, Portsmouth PO1 3QL, UK
‖ Department of Geology, Royal Holloway University of London, Egham Hill, Surrey TW20 0EX, UK



Nature, 2002

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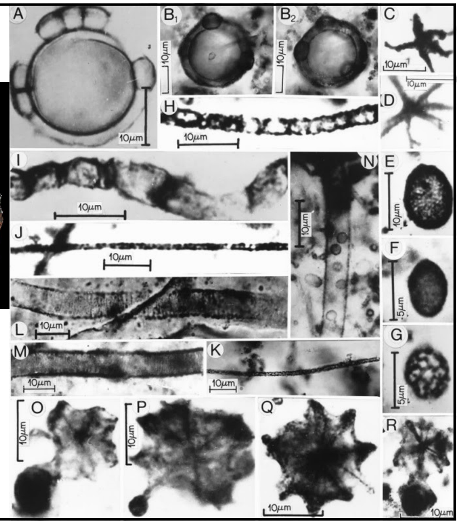
Biota de Gunflint



Ambiente de submaré
Associados a BIFs
16 táxons reconhecidos
6 txs de afinidade biológica desconhecida

26

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SCIENTIFIC REPORTS
natureresearch

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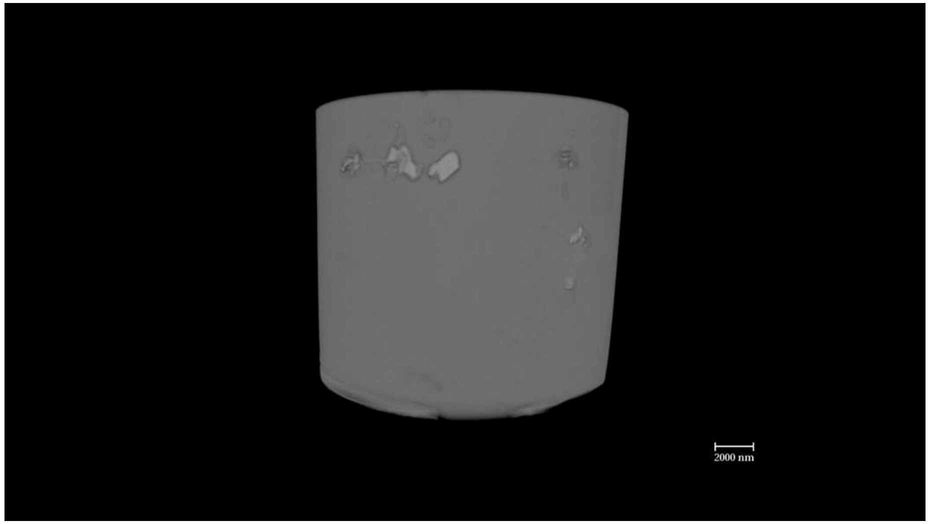
OPEN

Nanoscale 3D quantitative imaging of 1.88 Ga Gunflint microfossils reveals novel insights into taphonomic and biogenic characters

L. Maldanis[1,2,11], K. Hickman-Lewis[3,4], M. Verezhak[5], P. Gueriau[6,12], M. Guizar-Sicairos[5], P. Jaqueto[7], R. I. F. Trindade[7], A. L. Rossi[8], F. Berenguer[9], F. Westall[3], L. Bertrand[6,10] & D. Galante[1]

27



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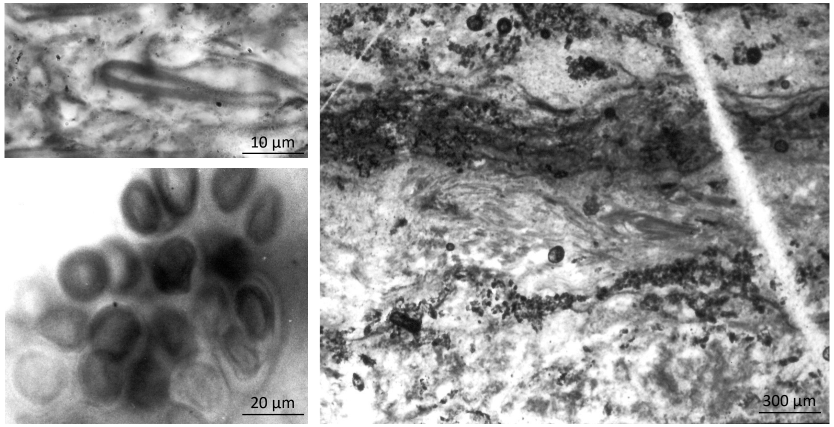
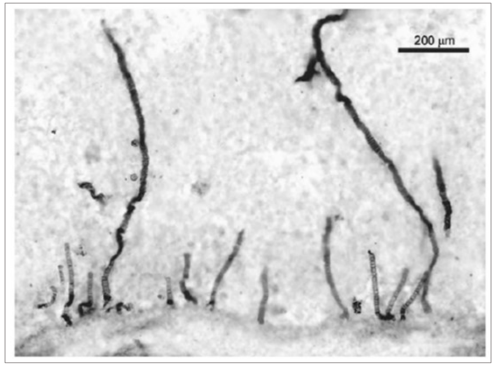
Esteiras microbianas

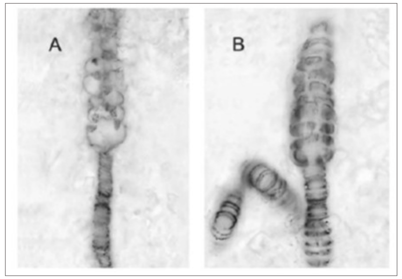


Fotos: T.R. Fairchild (IGc, USP)

29



Bangiomorpha pubesces **Butterfield 2000**
Mesoproterozoico, Canadá



Dimorfismo sexual

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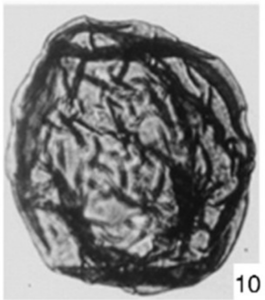
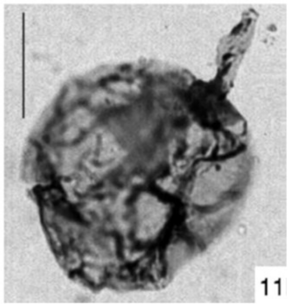
Acritarcos





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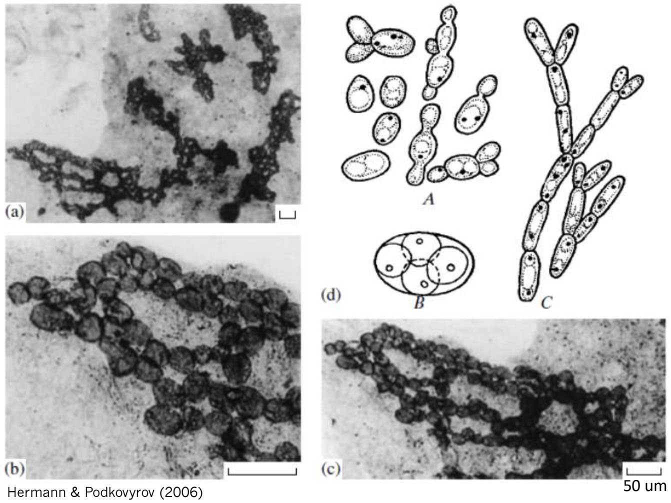

Hermann & Podkovyrov (2006)

Fungos

Fóssil mais antigo:
1.0 Ga,
Série Lakhanda,
Sibéria

Relógios
moleculares: 1.5 Ga

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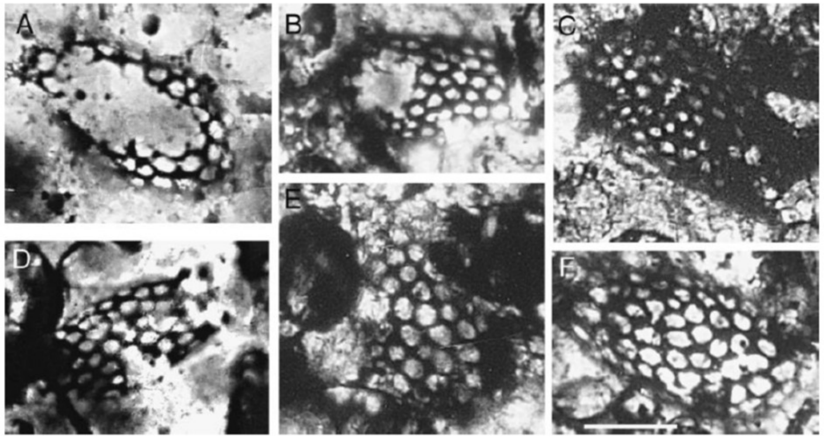
Vase-shaped microfossils



Porter & Knoll, 2000

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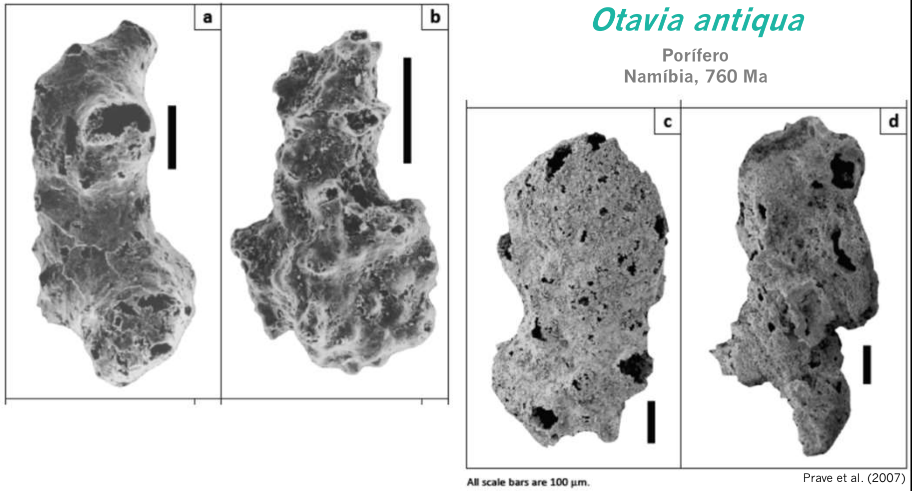
Otavia antiqua

Porífero
Namíbia, 760 Ma



Prave et al. (2007)

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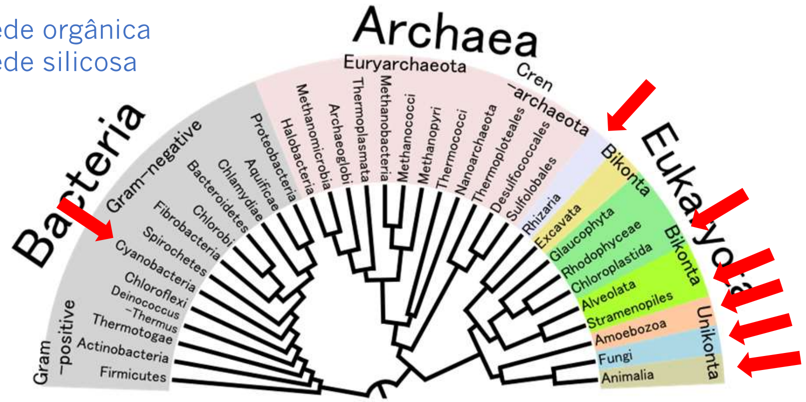
Microfósseis do Pré-Cambriano

Parede orgânica
Parede silicosa



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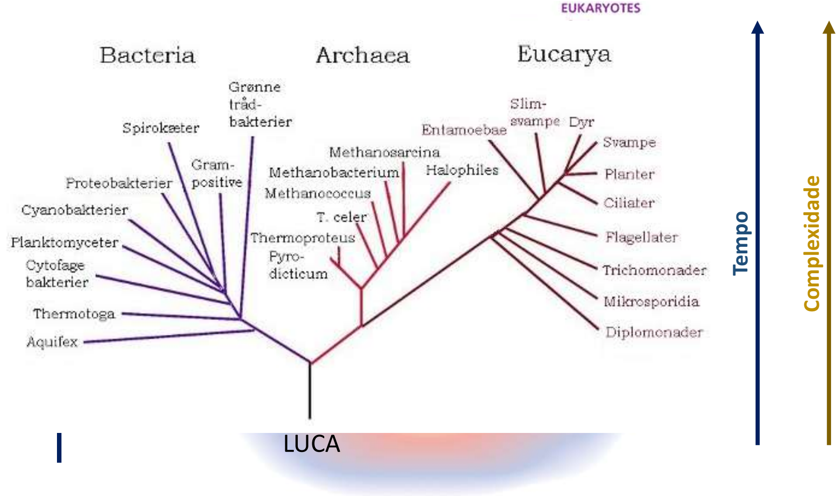

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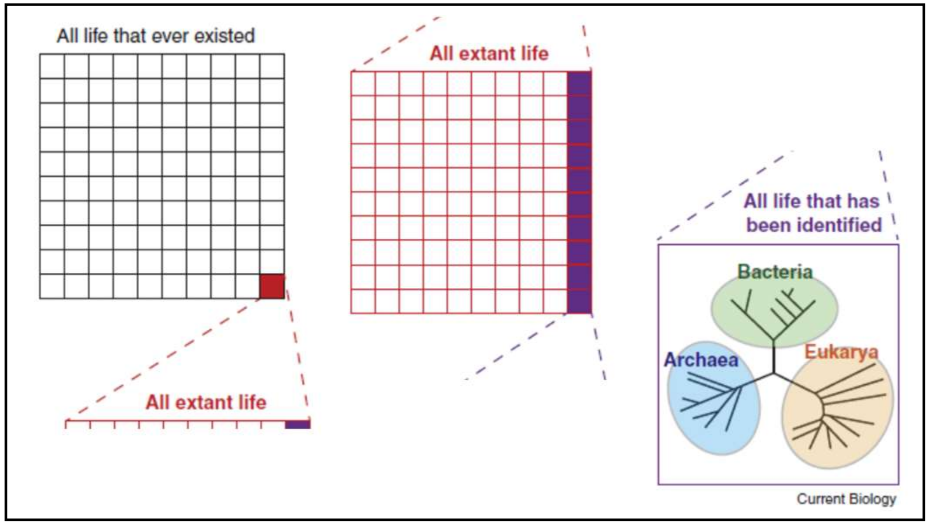
All life that ever existed
All extant life
All extant life
All life that has been identified
Bacteria
Archaea
Eukarya
Current Biology

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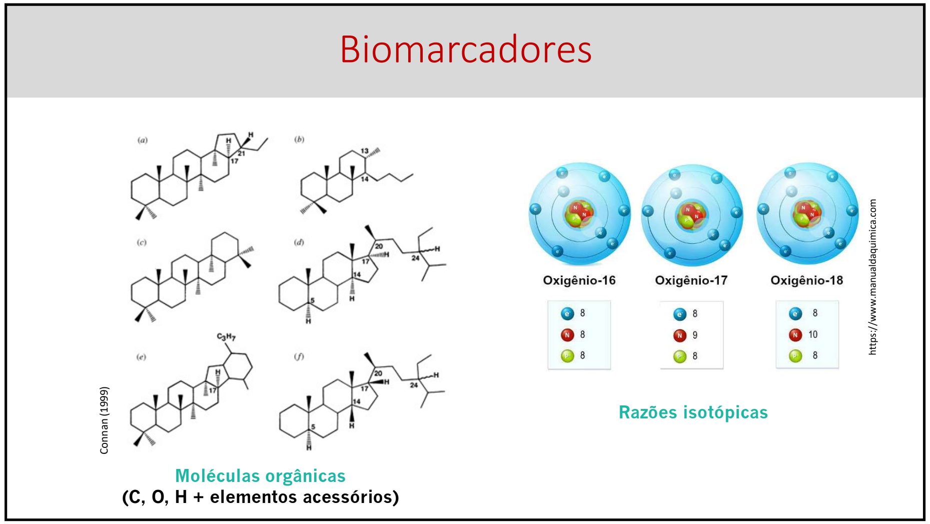
Biomarcadores
Connan (1999)
Moléculas orgânicas
(C, O, H + elementos acessórios)
Oxigênio-16
Oxigênio-17
Oxigênio-18
Razões isotópicas
https://www.manualdaquimica.com

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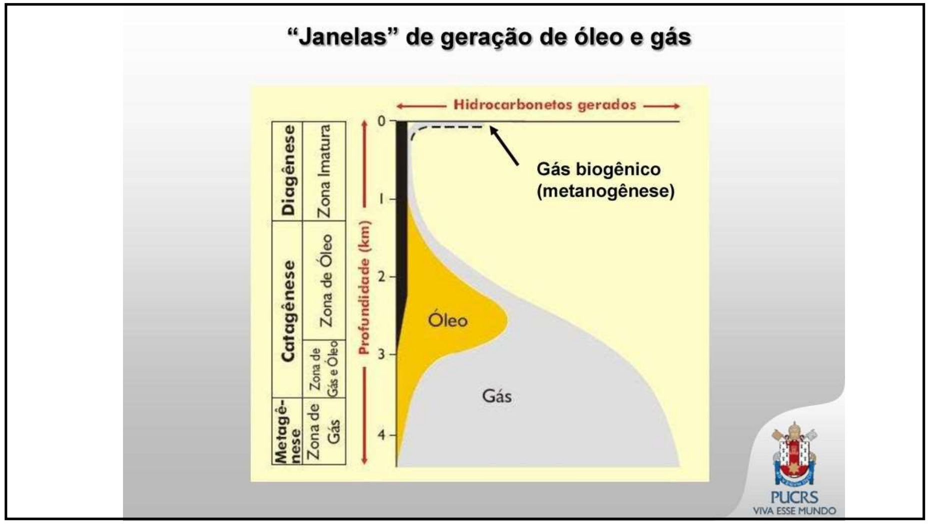
"Janelas" de geração de óleo e gás
Hidrocarbonetos gerados
Diagênese
Zona Imatura
Catagênese
Zona de Óleo
Zona de Gás e Óleo
Metagênese
Zona de Gás
Profundidade (km)
Gás biogênico
(metanogênese)
Óleo
Gás
PUCRS
VIVA ESSE MUNDO

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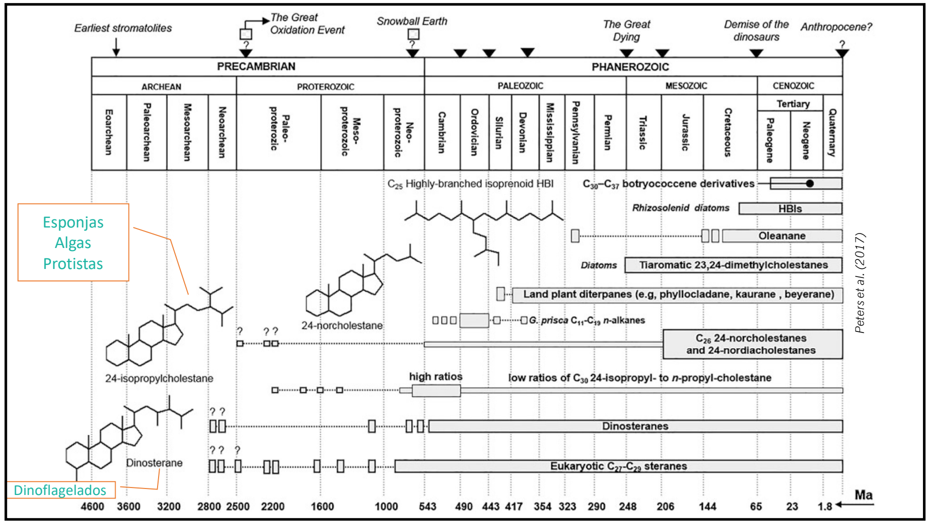
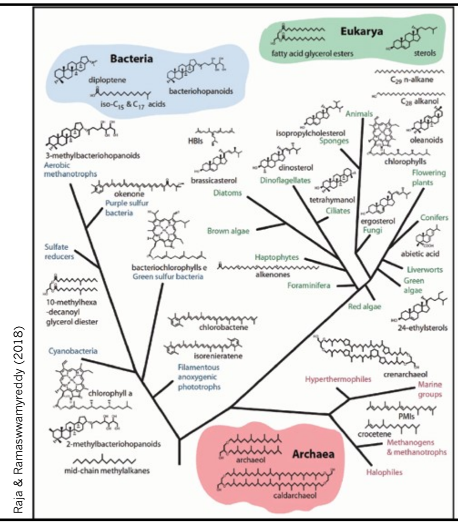
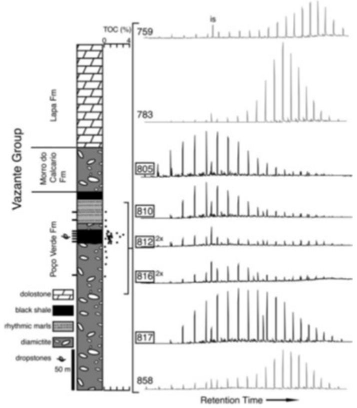

Earliest stromatolites
The Great Oxidation Event
Snowball Earth
The Great Dying
Demise of the dinosaurs
Anthropocene?
PRECAMBRIAN
PHANEROZOIC
ARCHEAN
PROTEROZOIC
PALEOZOIC
MESOZOIC
CENOZOIC
Tertiary
Eoarchean
Paleoarchean
Mesoarchean
Neoarchean
Paleo-proterozoic
Meso-proterozoic
Neo-proterozoic
Cambrian
Ordovician
Silurian
Devonian
Mississippian
Pennsylvanian
Permian
Triassic
Jurassic
Cretaceous
Paleogene
Neogene
Quaternary
Esponjas
Algas
Protistas
C25 Highly-branched isoprenoid HBI
C30–C37 botryococcene derivatives
Rhizosolenid diatoms
HBIs
Oleanane
Diatoms
Triaromatic 23,24-dimethylcholestanes
Land plant diterpanes (e.g, phyllocladane, kaurane, beyerane)
G. prisca C11–C19 n-alkanes
24-norcholestane
C26 24-norcholestanes and 24-nordiacholestanes
24-isopropylcholestane
high ratios
low ratios of C30 24-isopropyl- to n-propyl-cholestane
Dinosteranes
Dinosterane
Eukaryotic C27–C29 steranes
Dinoflagelados
Peters et al. (2017)
4600 3600 3200 2800 2500 2200 1600 1000 543 490 443 417 354 323 290 248 206 144 65 23 1.8
Ma

40



Biomarker Evidence for Photosynthesis During Neoproterozoic Glaciation



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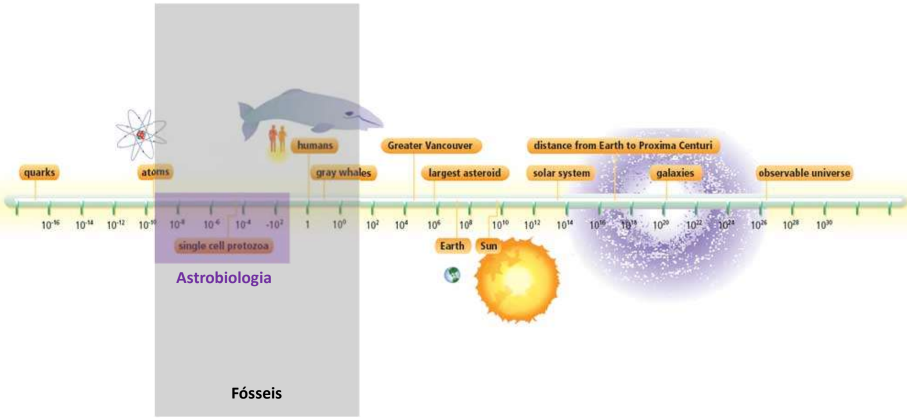
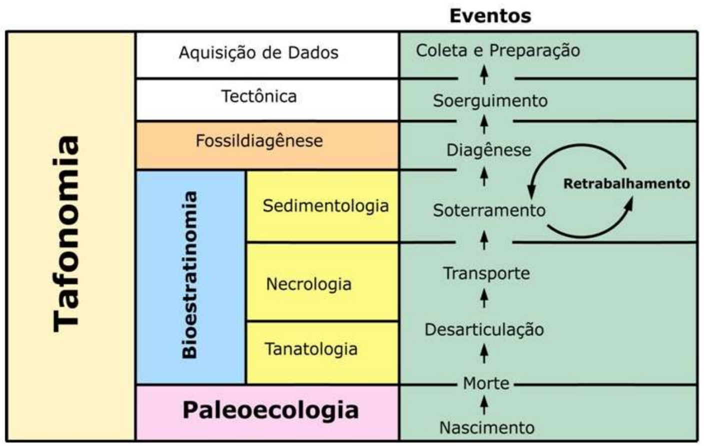


42



Fonte: http://www.ufrgs.br/paleodigital/Tafonomia.html

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Fósseis do Pré-Cambriano ✔

Astrobiologia

Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia

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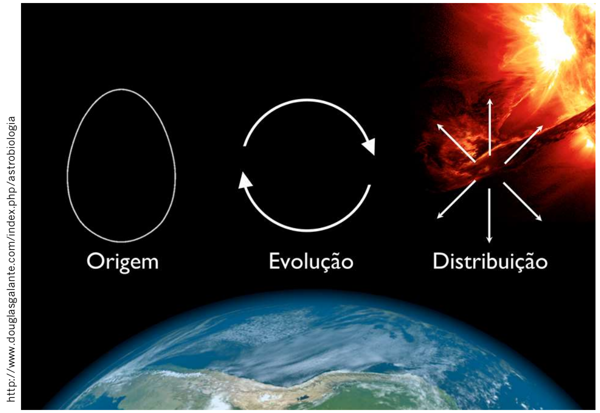
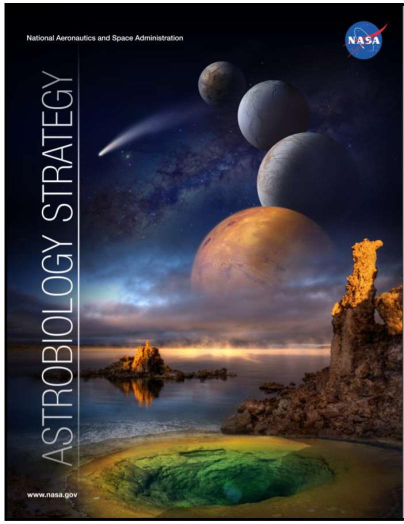
Astrobiologia



Vida no contexto do Universo

Ciência multidisciplinar

45



Identificando fontes abióticas de compostos orgânicos

Síntese e função das macromoléculas na origem da vida

Vida primitiva e aumento da complexidade

Co-evolução da vida e do ambiente físico

Identificando, explorando e caracterizando ambientes para habitabilidade e bioassinaturas

Construindo mundos habitáveis

Além das ciências naturais: humanidades e contribuições da ciência social à Astrobiologia

https://astrobiology.nasa.gov

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Fósseis do Pré-Cambriano ✔

Astrobiologia ✔

Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia

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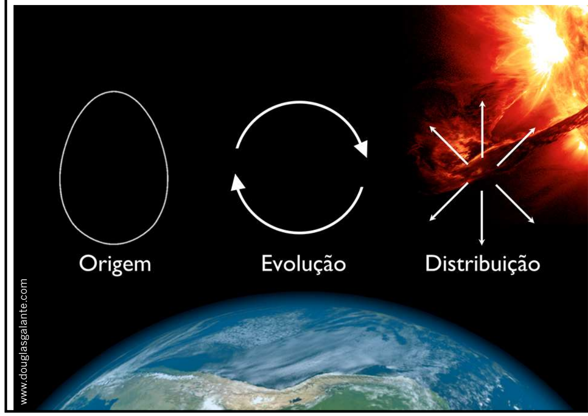
Fósseis e sua aplicação em Astrobiologia



Vida no contexto do Universo

Vida atual?

Vida pretérita?

Qual parâmetro utilizar?

Vida terrestre!

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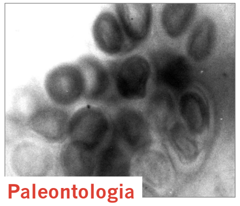
Fósseis e sua aplicação em Astrobiologia

Vida no contexto do Universo

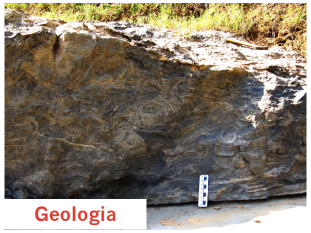
Vida atual?

Microbiologia ambiental

Vida pretérita?



Paleontologia



Geologia

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Fósseis e sua aplicação em Astrobiologia

MODELAGENS

SIMULAÇÕES

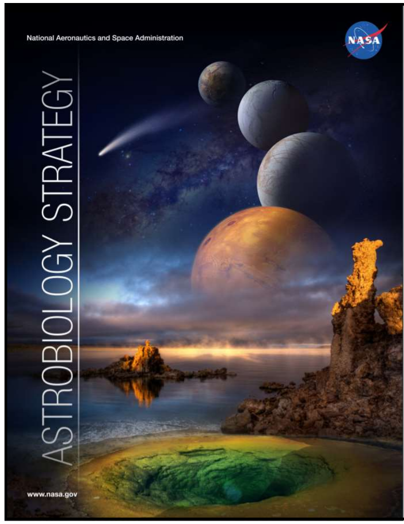
Desenvolvimento tecnológico

50

Condições Extremas

Condições semelhantes ao do ambientes no espaço: muito frio, muito calor, ausência de água, atmosferas variadas, alta radiação, alta pressão ou ainda com pH extremos.

51



Identificando fontes abióticas de compostos orgânicos

Síntese e função das macromoléculas na origem da vida

Vida primitiva e aumento da complexidade

Co-evolução da vida e do ambiente físico

Identificando, explorando e caracterizando ambientes para habitabilidade e bioassinaturas

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Cinco linhas de pesquisa para a busca de vida pretérita em outras superfícies:
✓ Microfósseis
✓ Biomarcadores
✓ Biominerais ou interação microorganismos/minerais
✓ Biointemperismo
✓ Estruturas sedimentares

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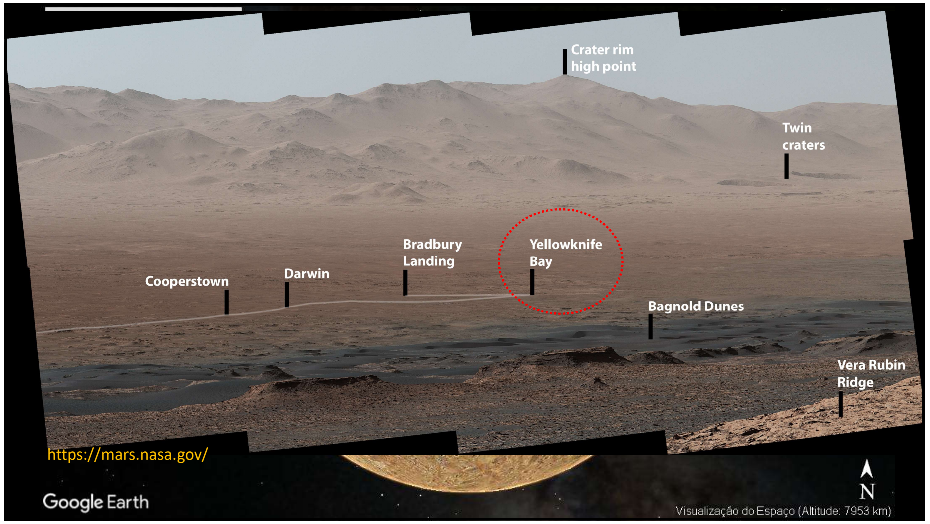
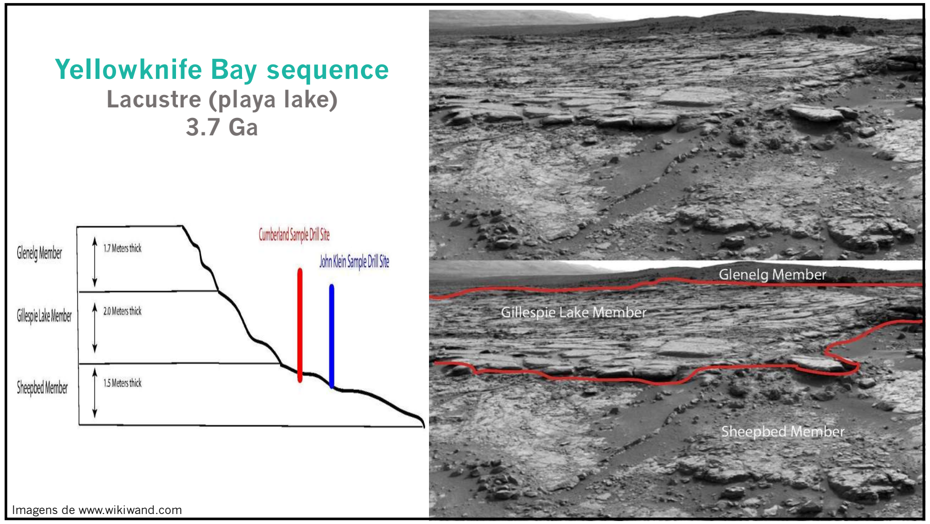
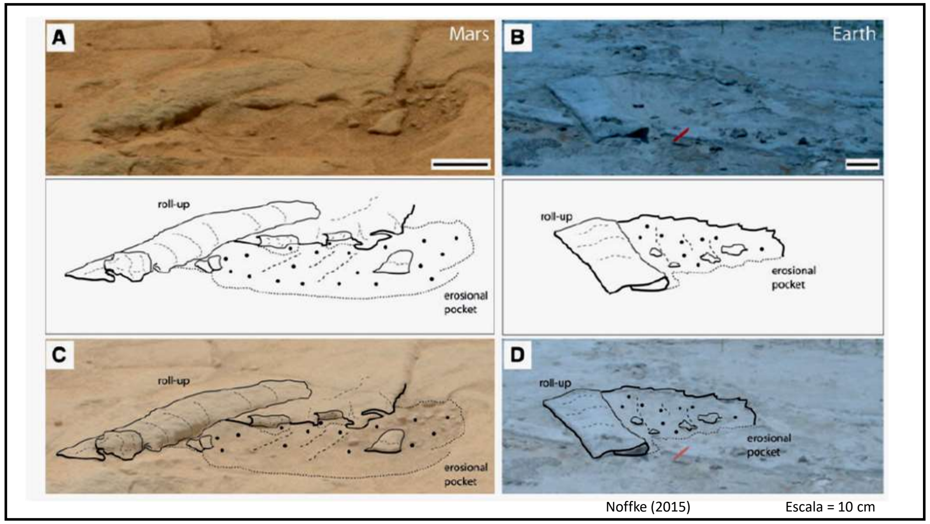

Crater rim high point
Twin craters
Cooperstown
Darwin
Bradbury Landing
Yellowknife Bay
Bagnold Dunes
Vera Rubin Ridge
https://mars.nasa.gov/
Google Earth
N
Visualização do Espaço (Altitude: 7953 km)

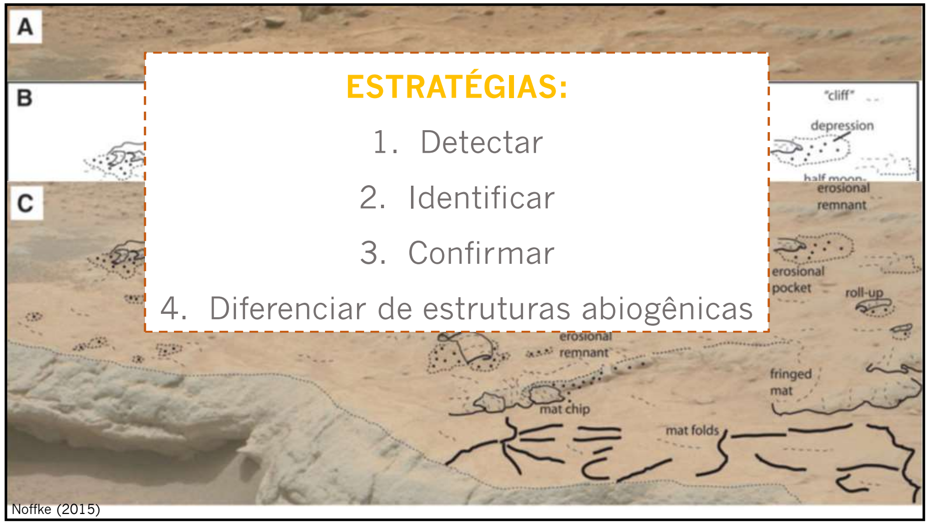
54


Yellowknife Bay sequence
Lacustre (playa lake)
3.7 Ga
Glenelg Member
Gillespie Lake Member
Sheepbed Member
1.7 Meters thick
2.0 Meters thick
1.5 Meters thick
Cumberland Sample Drill Site
John Klein Sample Drill Site
Glenelg Member
Gillespie Lake Member
Sheepbed Member
Imagens de www.wikiwand.com

55


A
Mars
B
Earth
roll-up
erosional pocket
roll-up
erosional pocket
C
roll-up
erosional pocket
D
roll-up
erosional pocket
Noffke (2015)
Escala = 10 cm

56



ESTRATÉGIAS:

1. Detectar
2. Identificar
3. Confirmar
4. Diferenciar de estruturas abiogênicas

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Perspectivas

1. **Quando a vida teria se estabelecido em Marte?**
2. **Onde a vida teria se estabelecido em Marte?**
3. **Para onde a vida teria se expandido (colonizado)?**
4. **Onde a vida teria persistido?**

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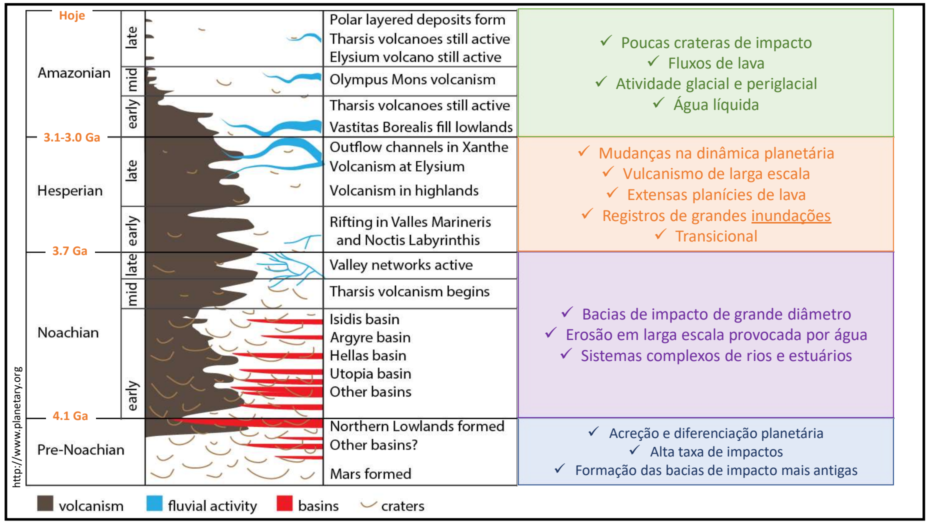

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Paleoambientes

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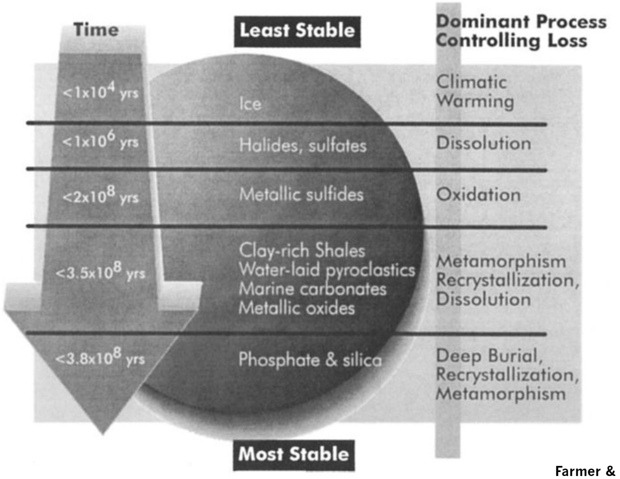
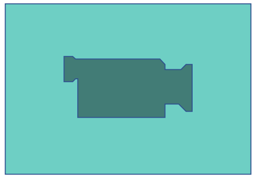


Farmer & Des Marais (1999)

61



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Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia

Parnell et al. (2007)

TABLE 2. SELECTION OF TARGET BIOMARKERS, THEIR LE

Target category no.	Priority	Biomarker	Mo
Extant			
1	A	ATP	Phos
2	A	Phosphoenolpyruvate	Phos
3	B	Acetyl phosphate	Phos
4	C	cyclic AMP	Phos
5	A	Generic pyrimidine base	Nucl
6	A	Generic purine base	Nucl
7	A	DNA	Nucl
8	A	Nicotinamide (generic NAD, NADP)	Vitan
9	C	Flavin (isoalloxazine ring)	Vitan
10	C	Fe-S centers	Redo
11	C	Quinones	Elect
12	B	Generic carotenoid	Pigm
13	C	Phycocyanin	Pigm
14	C	Thioesters	Ester
15	A	Generic extant porphyrin	Porpl
16	B	Chaperones	Prote
17	A	ATP Synthase	Prote
18	A	Phytane	Hydr
19	A	Fatty acids (1 or 2)	Carb

20	A	Teichoic acid	Amino acid + phosphate polymer	Yes	Gram-positive wall
21	A	LPS	Macromolecule	Yes	Gram-negative wall
22	B	Ectoine	Compatible solute	Yes	Osmotic protectant
23	C	Trehalose	Compatible solute	Yes	Osmotic protectant
24	B	Squalene	Hydrocarbon	No	Lipid biosynthesis (isoprenoid precursor)
25	C	Diploptene	Hopanoid	No	Bacterial membrane
26	B	Melanoidins	Macromolecule	No	Sugar degradation
		Sediment/cell extracts:			
27	C	1. Acid mine drainage	Multiple	Some	Whole cells
28	C	2. Methanogens	Multiple	Some	Whole cells
29	C	3. Cyanobacteria	Multiple	Some	Whole cells
30	C	4. Mars energy users	Multiple	Some	Whole cells
31	C	5. Extract/abiotic mix	Multiple	Some	Whole cells
Fossil					
32	A	Generic isoprenoid	Hydrocarbon	No	Chlorophyll, quinones, archeal membranes
33	A	Pristane	Hydrocarbon	No	Chlorophyll, quinones, archeal membranes
18	A	Phytane	Hydrocarbon	No	Chlorophyll, quinones, archeal membranes
34	A	β,β-carotane	Hydrocarbon	No	Fossil carotenoids
35	C	Tetramethyl benzenes	Hydrocarbon	No	Fossil carotenoids
36	C	Tetramethyl cyclohexanes	Hydrocarbon	No	Fossil carotenoids
37	C	Squalane	Hydrocarbon	No	Membranes (prokaryotes)
38	A	Generic ABC terpane	Hydrocarbon	No	Membranes (prokaryotes)
39	A	Generic hopane	Hydrocarbon	No	Membranes (prokaryotes)
40	C	Gammacerane	Hydrocarbon	No	Membranes (prokaryotes)
41	B	Generic diasterane	Hydrocarbon	No	Membranes (eukaryotes and prokaryotes)

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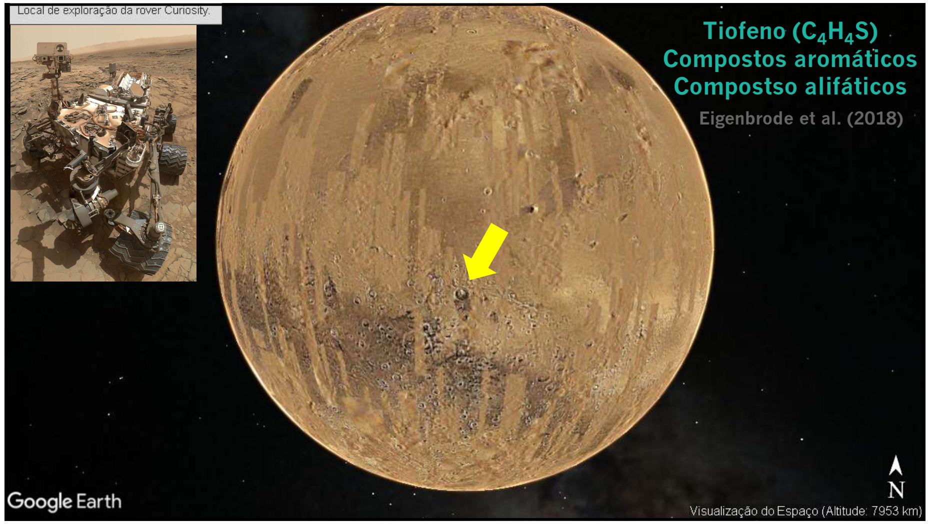
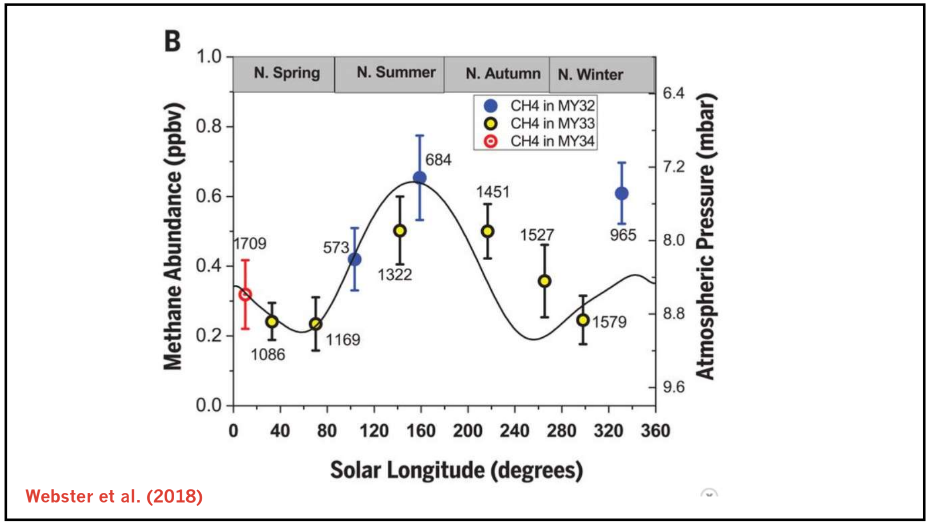
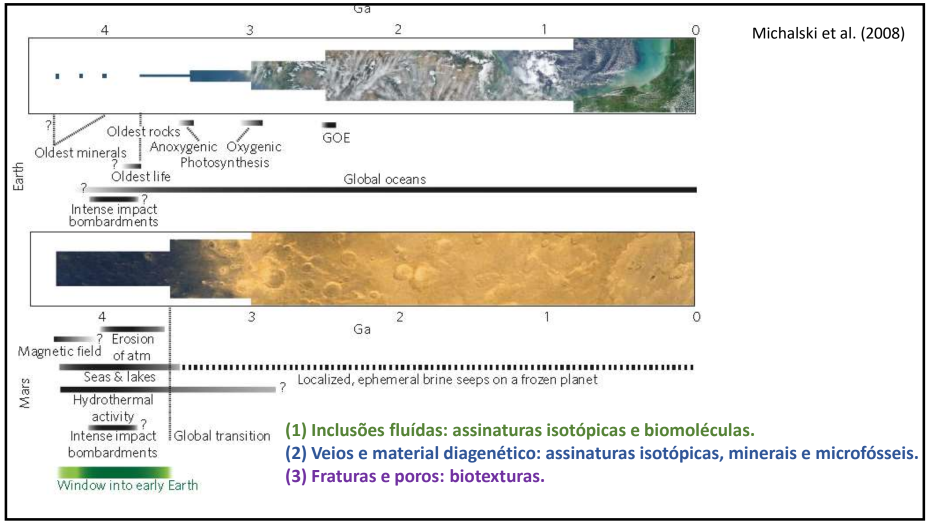

Local de exploração da rover Curiosity.
Tiofeno (C_4H_4S)
Compostos aromáticos
Compostso alifáticos
Eigenbrode et al. (2018)
Google Earth
N
Visualização do Espaço (Altitude: 7953 km)

65


B
N. Spring
N. Summer
N. Autumn
N. Winter
CH4 in MY32
CH4 in MY33
CH4 in MY34
Methane Abundance (ppbv)
Atmospheric Pressure (mbar)
Solar Longitude (degrees)
1709
1086
1169
573
1322
684
1451
1527
965
1579
Webster et al. (2018)

66


Michalski et al. (2008)
Ga
Earth
Oldest rocks
Oldest minerals
Anoxygenic
Oxygenic
Photosynthesis
GOE
Oldest life
Global oceans
Intense impact
bombardments
Mars
Magnetic field
Erosion
of atm
Seas & lakes
Localized, ephemeral brine seeps on a frozen planet
Hydrothermal
activity
Intense impact
bombardments
Global transition
Window into early Earth
(1) Inclusões fluídas: assinaturas isotópicas e biomoléculas.
(2) Veios e material diagenético: assinaturas isotópicas, minerais e microfósseis.
(3) Fraturas e poros: biotexturas.

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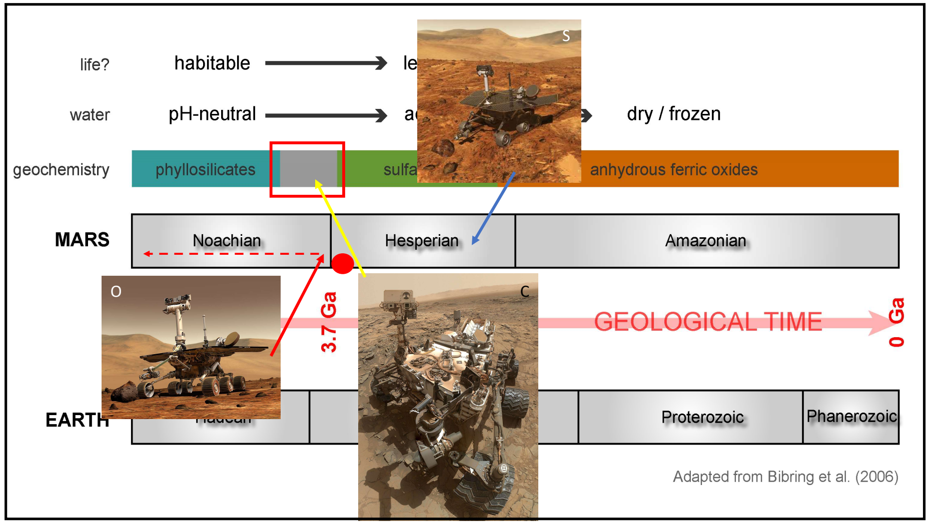
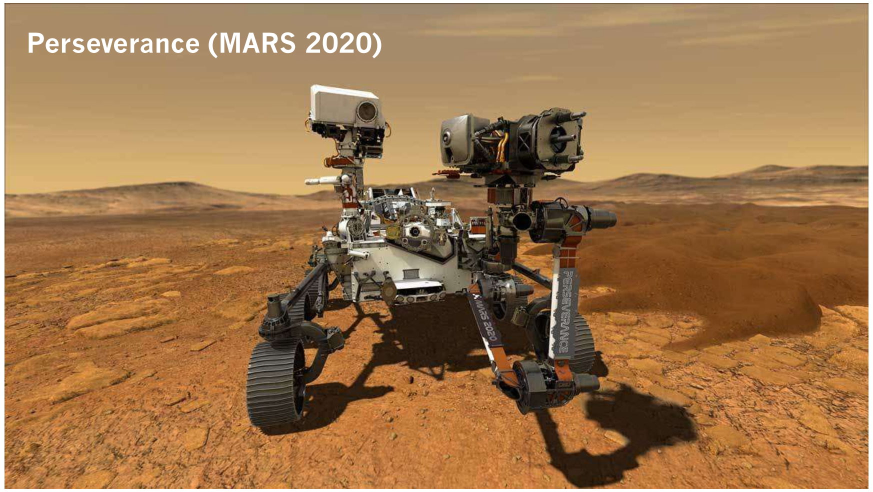
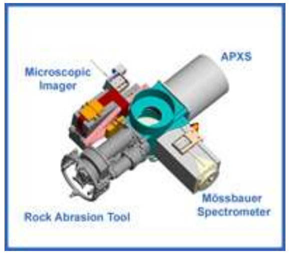

life?
habitable
water
pH-neutral
dry / frozen
geochemistry
phyllosilicates
anhydrous ferric oxides
MARS
Noachian
Hesperian
Amazonian
GEOLOGICAL TIME
3.7 Ga
0 Ga
EARTH
Proterozoic
Phanerozoic
Adapted from Bibring et al. (2006)

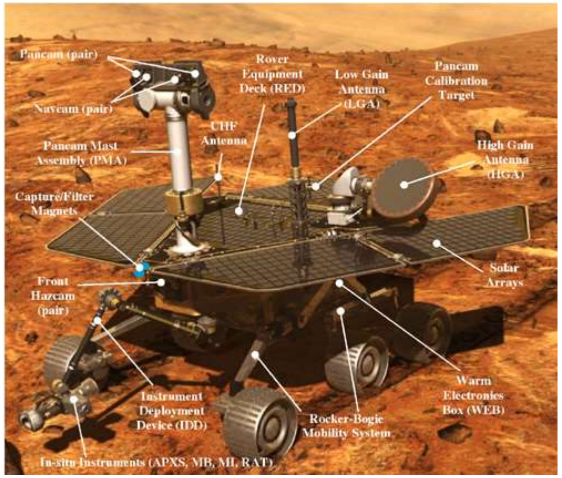
68



69



Tecnologias para a procura e identificação



mars.nasa.gov

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Fósseis do Pré-Cambriano ✓

Astrobiologia ✓

Fósseis do Pré-Cambriano e sua aplicação em Astrobiologia ✓

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Conclusão

Entender o que é vida

Entender a vida moderna:
- os limites fisiológicos

Entender vida pretérita:
- Forma
- Paleoecologia/Paleoambientes
- Evolução
- Preservação
- Modelos

Processos e Produtos

Buscar vida pretérita:
- Preservação
- Modelos
- Paleoecologia/Paleoambientes
- Forma

Produtos e Processos

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Recomendações

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Trabalho de Clair Patterson e a datação do Planeta Terra

S01 – E07


Geochimica et Cosmochimica Acta, 1956, Vol. 10, pp. 230 to 237. Pergamon Press Ltd., London

Age of meteorites and the earth

CLAIRE PATTERSON
Division of Geological Sciences
California Institute of Technology, Pasadena, California

(*Received* 23 *January* 1956)

Abstract—Within experimental error, meteorites have one age as determined by three independent radiometric methods. The most accurate method (Pb^{207}/Pb^{206}) gives an age of $4 \cdot 55 \pm 0 \cdot 07 \times 10^9$ yr. Using certain assumptions which are apparently justified, one can define the isotopic evolution of lead for any meteoritic body. It is found that earth lead meets the requirements of this definition. It is therefore believed that the age for the earth is the same as for meteorites. This is the time since the earth attained its present mass.

IT seems we now should admit that the age of the earth is known as accurately and with about as much confidence as the concentration of aluminium is known in the Westerly, Rhode Island granite. Good estimates of the earth's age have been known for some time. After the decay-constant of U^{235} and the isotopic compositions of common earth-leads were determined by NIER, initial calculations, such as GERLING's, roughly defined the situation. Approximately correct calculations were made by HOLMES and by HOUTERMANS on the basis of bold assumptions concerning the genesis of lead ores. Subsequent criticism of these calculations created an air of doubt about anything concerning common leads and obscured the indispensable contributions which these investigators made in establishing the new science of the geochemistry of lead isotopes. When the isotopic composition of lead from an iron meteorite was determined, we were able to show that a much more accurate calculation of the earth's age could be made, but it still was impossible to defend the computation. Now, we know the isotopic compositions of leads from some stone meteorites and we can make an explicit and logical argument for the computation which is valid and persuasive.

The most accurate age of meteorites is determined by first assuming that meteorites represent an array of uranium-lead systems with certain properties,

https://doi.org/10.1016/0016-7037(56)90036-9

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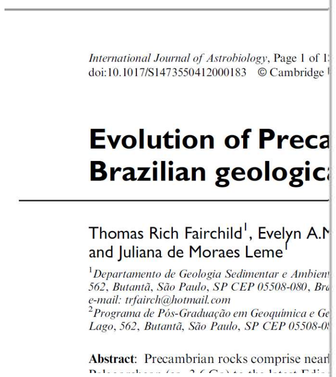
International Journal of Astrobiology, Page 1 of 1
doi:10.1017/S1473550412000183 © Cambridge

Evolution of Preca
Brazilian geologic

Thomas Rich Fairchild[1], Evelyn A.N
and Juliana de Moraes Leme[1]
[1]*Departamento de Geologia Sedimentar e Ambien*
562, Butantã, São Paulo, SP CEP 05508-080, Br
e-mail: trfairch@hotmail.com
[2]*Programa de Pós-Graduação em Geoquímica e Ge*
Lago, 562, Butantã, São Paulo, SP CEP 05508-0

Abstract: Precambrian rocks comprise near

http://journals.cambridge.org/abstract_S14

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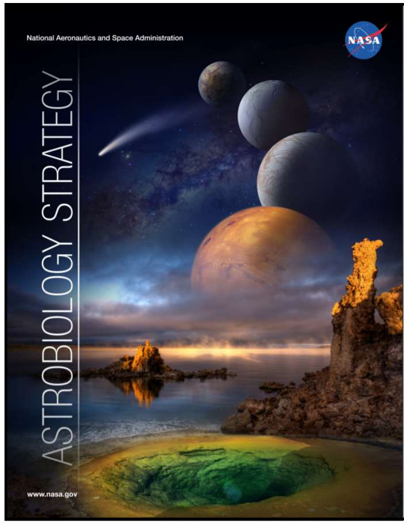

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AstroLab
Universidade de São Paulo

http://tikinet.kinghost.net/astrobiologia.pdf

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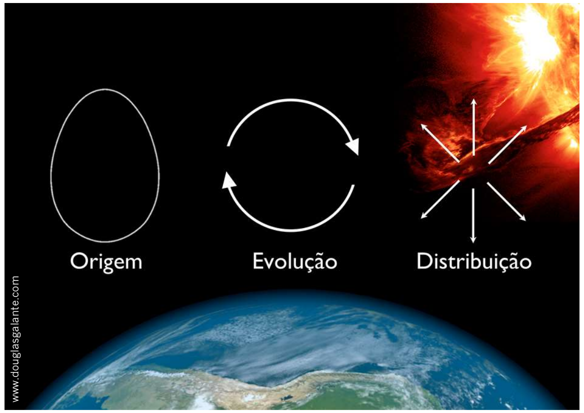

Muito obrigada!

evelyn.sanchez@ict.ufvjm.edu.br

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