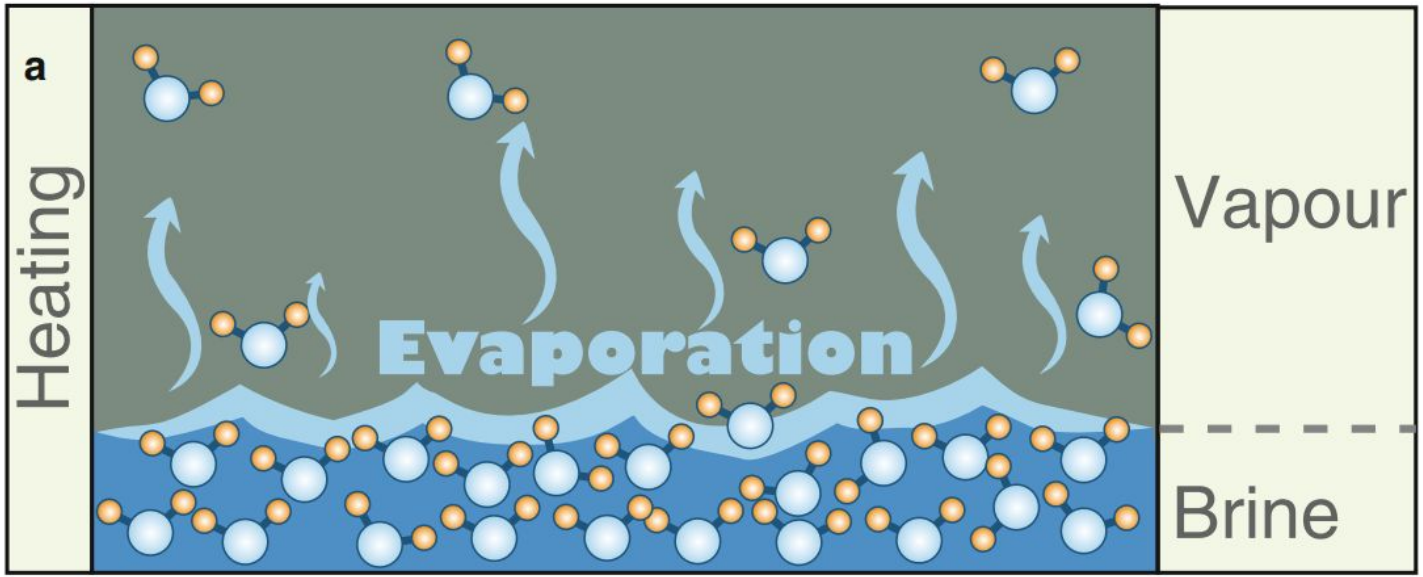
Sedimentos e rochas evaporíticas

GSA0621

O que são evaporitos?

Definição de evaporitos

Depósito sedimentar formado na superfície, ou próximo à superfície, a partir da concentração e precipitação de sais dissolvidos em meio aquoso devido a evaporação solar.



Warren 2016

Redução do volume d’água

Precipitação subaquática (lagos ou lagunas)

Precipitação subaérea (sabkhas)

Classificação

Autóctone

Alóctone

Detrítico

Terrígeno

Intrabacinal

Extrabacinal

Autigênico

Biogênico

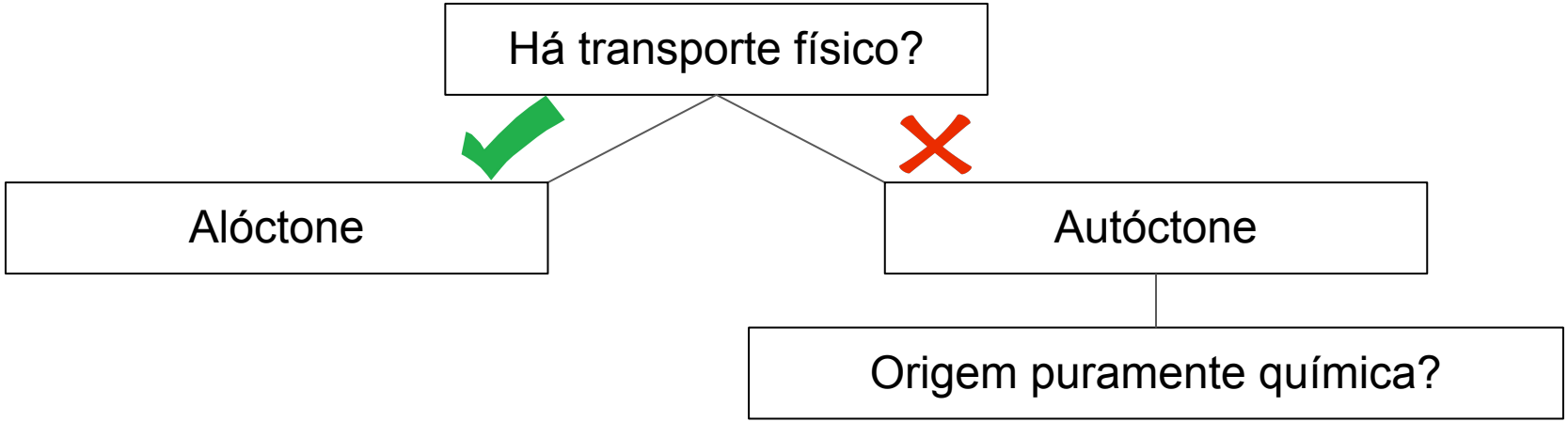
Bioconstruído

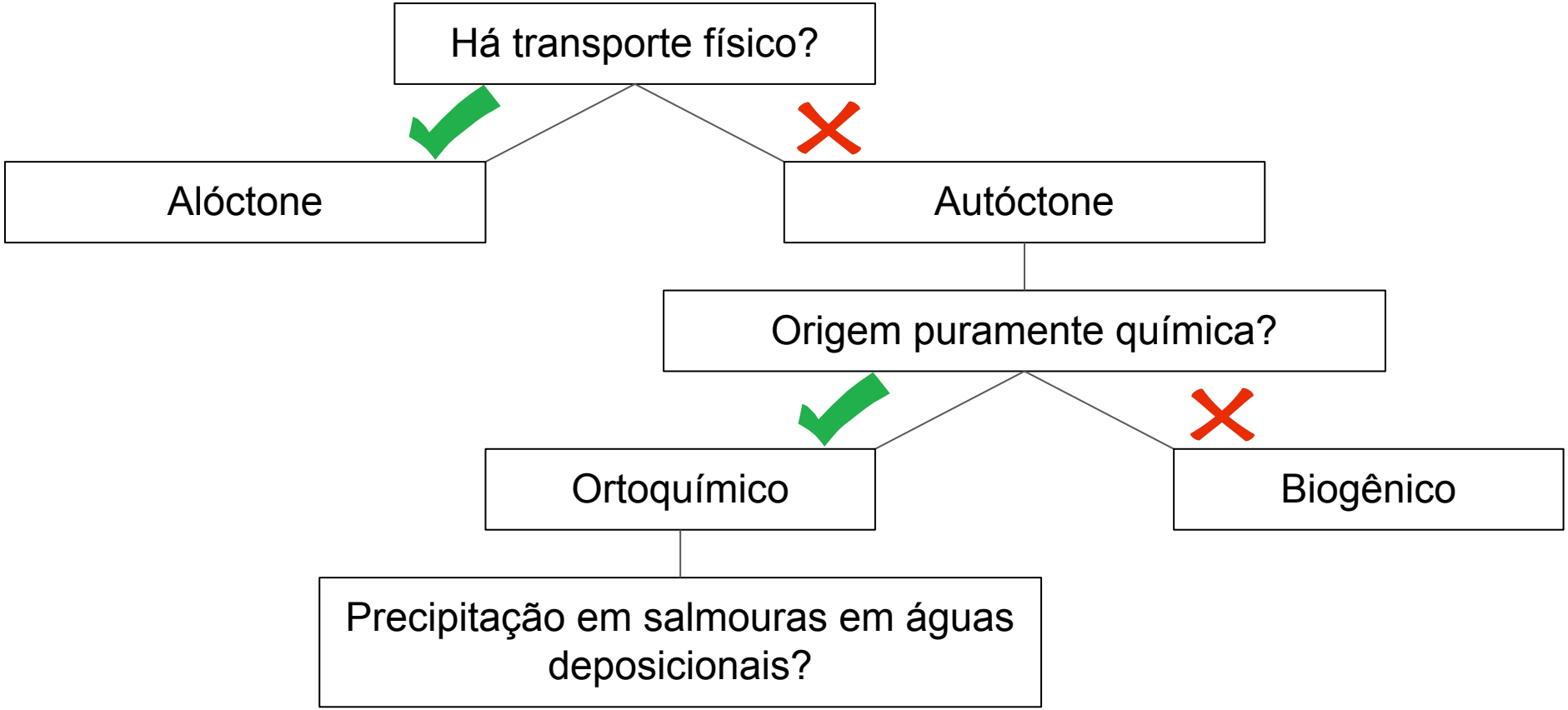
Bioinduzido

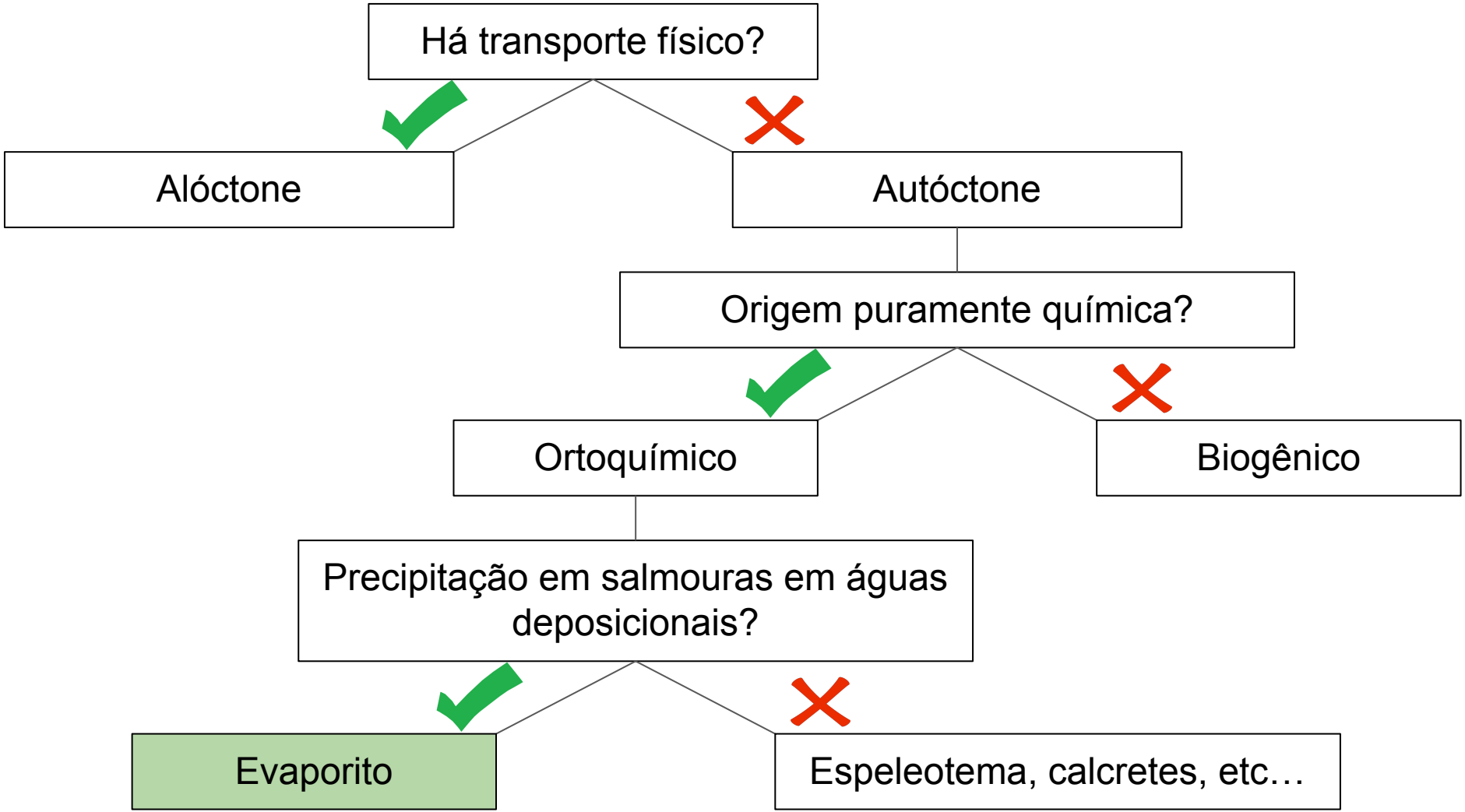
Ortoquímico

Orgânico

Há transporte físico?


Há transporte físico?
Alóctone
Autóctone
Origem puramente química?


Há transporte físico?
Alóctone
Autóctone
Origem puramente química?
Ortoquímico
Biogênico
Precipitação em salmouras em águas deposicionais?


Há transporte físico?
Alóctone
Autóctone
Origem puramente química?
Ortoquímico
Biogênico
Precipitação em salmouras em águas deposicionais?
Evaporito
Espeleotema, calcretes, etc…

Mineral	Formula	Mineral	Formula
Anhydrite	$CaSO_4$	Leonhardtite	$MgSO_4{\cdot}4H_2O$
Antarcticite	$CaCl_2{\cdot}6H_2O$	Leonite	$MgSO_4{\cdot}K_2SO_4{\cdot}4H_2O$
Aphthitalite (glaserite)	$K_2SO_4{\cdot}(Na,K)SO_4$	Loewite	$2MgSO_4{\cdot}2Na_2SO4{\cdot}5H_2O$
Aragonite**	$CaCO_3$	Mg-calcite**	$(Mg_xCa_{1-x})CO_3$
Bassanite	$CaSO_4{\cdot}1/2H_2O$	Magnesite**	$MgCO_3$
Bischofite	$MgCl_2{\cdot}6H_2O$	Meyerhoffite	$Ca_2B_5O_{11}{\cdot}7H_2O$
Bloedite (astrakanite)	$Na_2SO_4{\cdot}MgSO_4{\cdot}4H_2O$	Mirabilite	$Na_2SO_4{\cdot}10H_2O$
Borax (tincal)	$Na_2B_4O_7{\cdot}10H_2O$	Nahcolite	$NaHCO_3$
Boracite	$Mg_3B_7O_{13}{\cdot}Cl$	Natron	$Na_2CO_3{\cdot}10H_2O$
Burkeite	$Na_2CO_3{\cdot}2Na_2SO_4$	Nitratite (soda nitre)	$NaNO_3$
Calcite**	$CaCO_3$	Nitre (salt petre)	KNO_3
Carnallite	$MgCl_2{\cdot}KCl{\cdot}6H_2O$	Pentahydrite	$MgSO_4{\cdot}5H_2O$
Colemanite	$Ca_2B_5O_{11}{\cdot}5H_2O$	Pirssonite	$CaCO_3{\cdot}Na_2CO_3{\cdot}2H_2O$
Darapskite	$NaSO_4{\cdot}NaNO_3{\cdot}H_2O$	Polyhalite	$2CaSO_4{\cdot}MgSO_4{\cdot}K_2SO_4{\cdot}H_2O$
Dolomite**	$Ca_{(1+x)}Mg_{(1-x)}(CO_3)_2$	Proberite	$NaCaB_5O_9{\cdot}5H_2O$
Epsomite	$MgSO_4{\cdot}7H_2O$	Priceite (pandermite)	$CaB_4O_{10}{\cdot}7H_2O$
Ferronatrite	$3NaSO_4{\cdot}Fe_2(SO_4)_3{\cdot}6H_2O$	Rinneite	$FeCl_2{\cdot}NaCl{\cdot}3KCl$
Gaylussite	$CaCO_3{\cdot}Na_2CO_3{\cdot}5H_2O$	Sanderite	$MgSO_4{\cdot}2H_2O$
Glauberite	$CaSO_4{\cdot}Na_2SO_4$	Schoenite (picromerite)	$MgSO_4{\cdot}K_2SO_4{\cdot}6H_2O$
Gypsum	$CaSO_4{\cdot}2H_2O$	Shortite	$2CaCO_3{\cdot}Na_2CO_3$
Halite	$NaCl$	Sylvite	KCl
Hanksite	$9Na_2SO_4{\cdot}2Na_2CO_3{\cdot}KCl$	Syngenite	$CaSO_4{\cdot}K_2SO_4{\cdot}H_2O$
Hexahydrite	$MgSO_4{\cdot}6H_2O$	Tachyhydrite	$CaCl_2{\cdot}2MgCl_2{\cdot}12H_2O$
Howlite	$H_5Ca_2SiB_5O_{14}$	Thernadite	Na_2SO_4
Ikaite**	$CaCO_3{\cdot}6H_2O$	Thermonatrite	$NaCO_3{\cdot}H_2O$
Inyoite	$Ca_2B_6O_{11}{\cdot}13H_2O$	Tincalconite	$Na_2B_4O_7{\cdot}5H_2O$
Kainite	$4MgSO_4{\cdot}4KCl{\cdot}11H_2O$	Trona	$NaHCO_3{\cdot}Na_2CO_3$
Kernite	$Na_2B_4O_7{\cdot}4H_2O$	Tychite	$2MgCO_3{\cdot}2NaCO_3{\cdot}Na_2SO_4$
Kieserite	$MgSO_4{\cdot}H_2O$	Ulexite	$NaCaB_5O_9{\cdot}5H_2O$
Langbeinite	$2MgSO_4{\cdot}K_2SO_4$	Vanthoffite	$MgSO_4{\cdot}3Na_2SO_4$

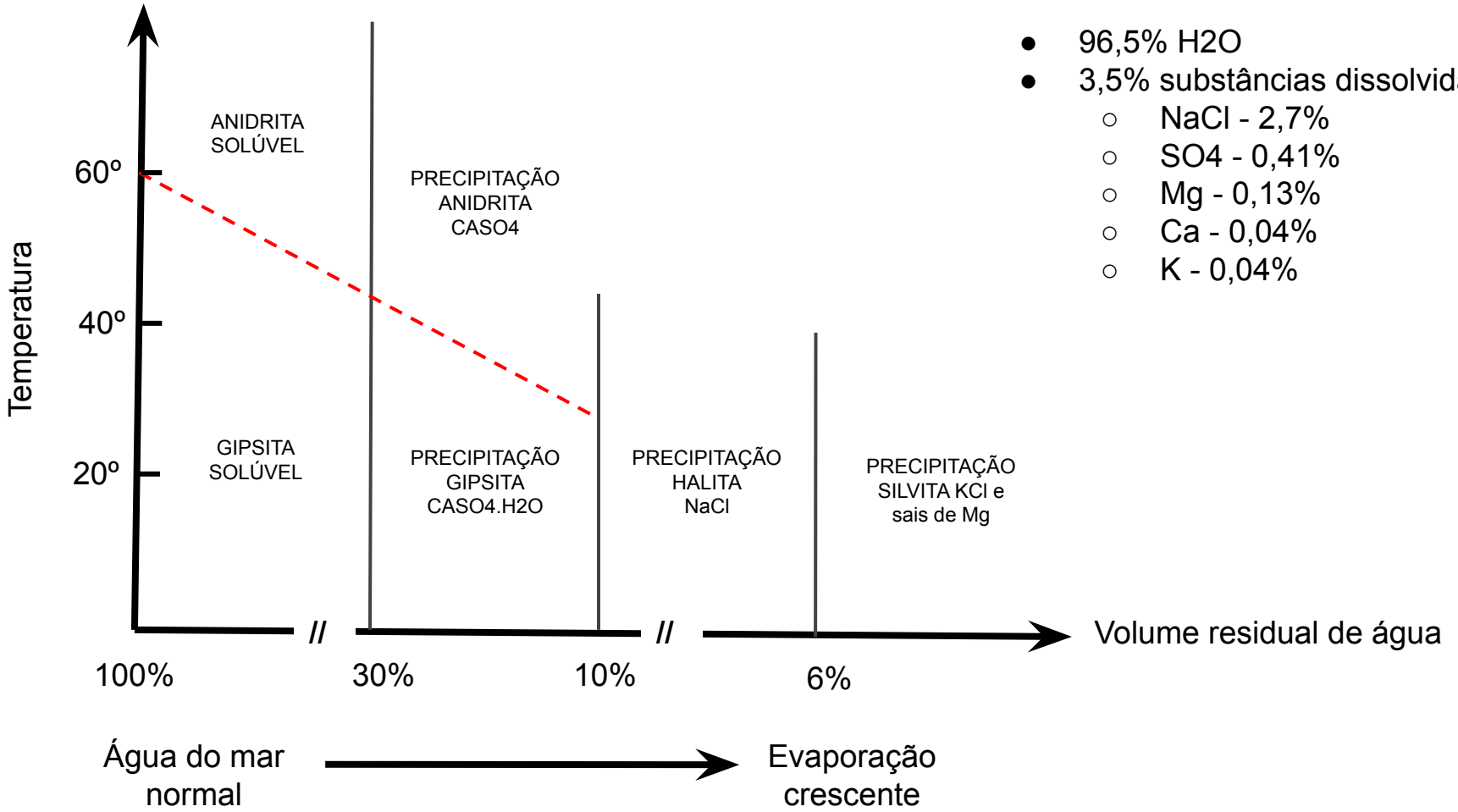
Principais minerais evaporíticos

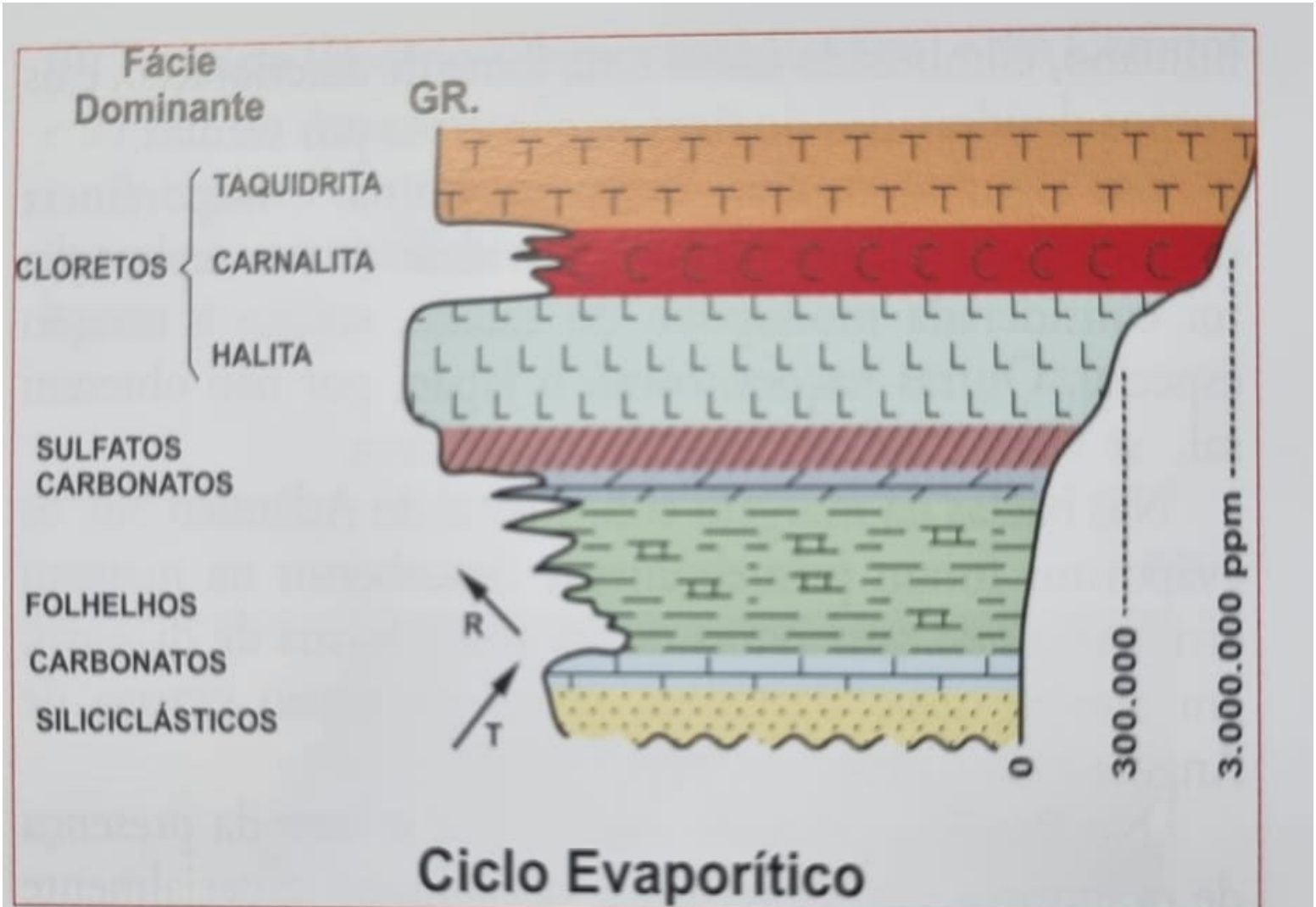
Todos evaporitos são sais iônicos contendo os principais íons Na, Ca, Mg, K, Cl, SO4, and CO3 em proporções variadas.

Warren 2016

Água do mar ‘normal’

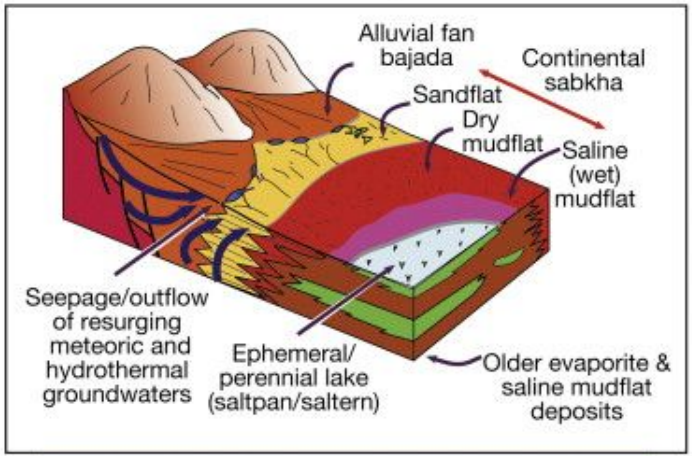
- 96,5% H2O
- 3,5% substâncias dissolvidas
  - NaCl - 2,7%
  - SO4 - 0,41%
  - Mg - 0,13%
  - Ca - 0,04%
  - K - 0,04%

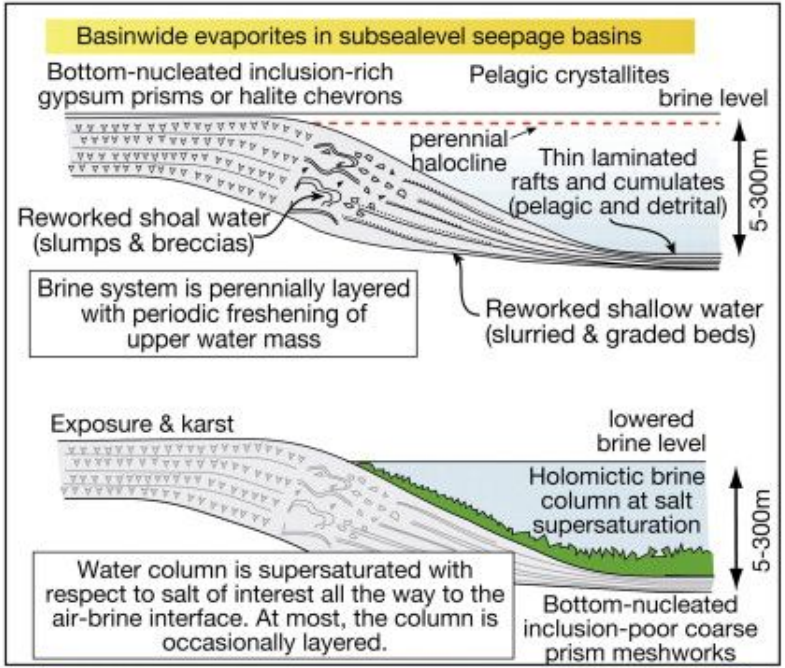




Ciclo Evaporítico

Depositional spectrum of ancient evaporite systems across deep time





CONTINENTAL (NONMARINE FEED)
sabkhas, saline pans, salt lakes

Quaternary analogues in texture, scale and hydrology
(borates, salt cake, soda ash
with halite and variable $CaSO_4$)

MARINE FEED
platform

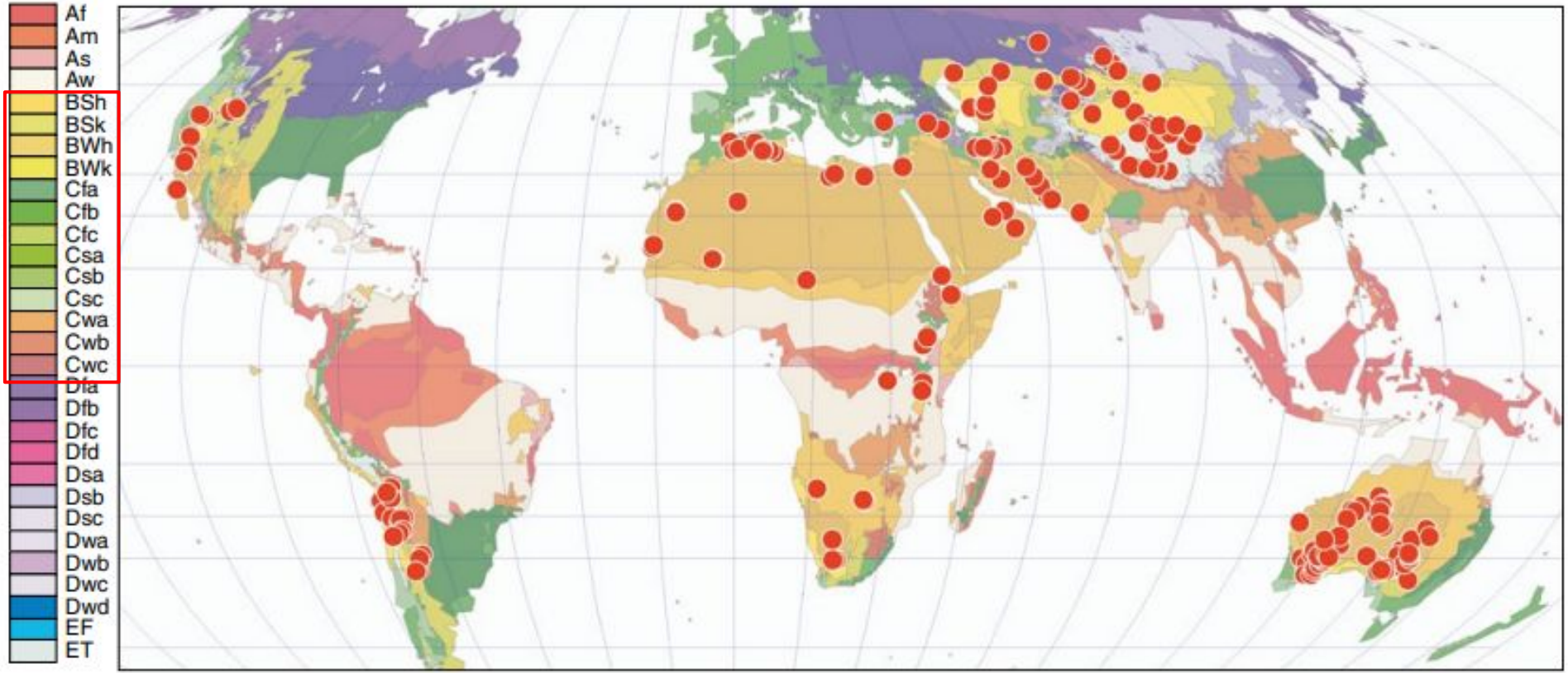
MARINE FEED
slope | basin

Partial textural analogues, no marine Quaternary
analogues in scale or tectonic setting
(potash, widespread thick halite and anhydrite)

Basinwide Spectrum

CONTINENTAL	PLATFORM	SLOPE & BASIN	BASINAL
sabkhas, salt lakes	ramp, shelf	slumps, turbidites	laminite or mesh

Distribuição dos evaporitos continentais quaternários



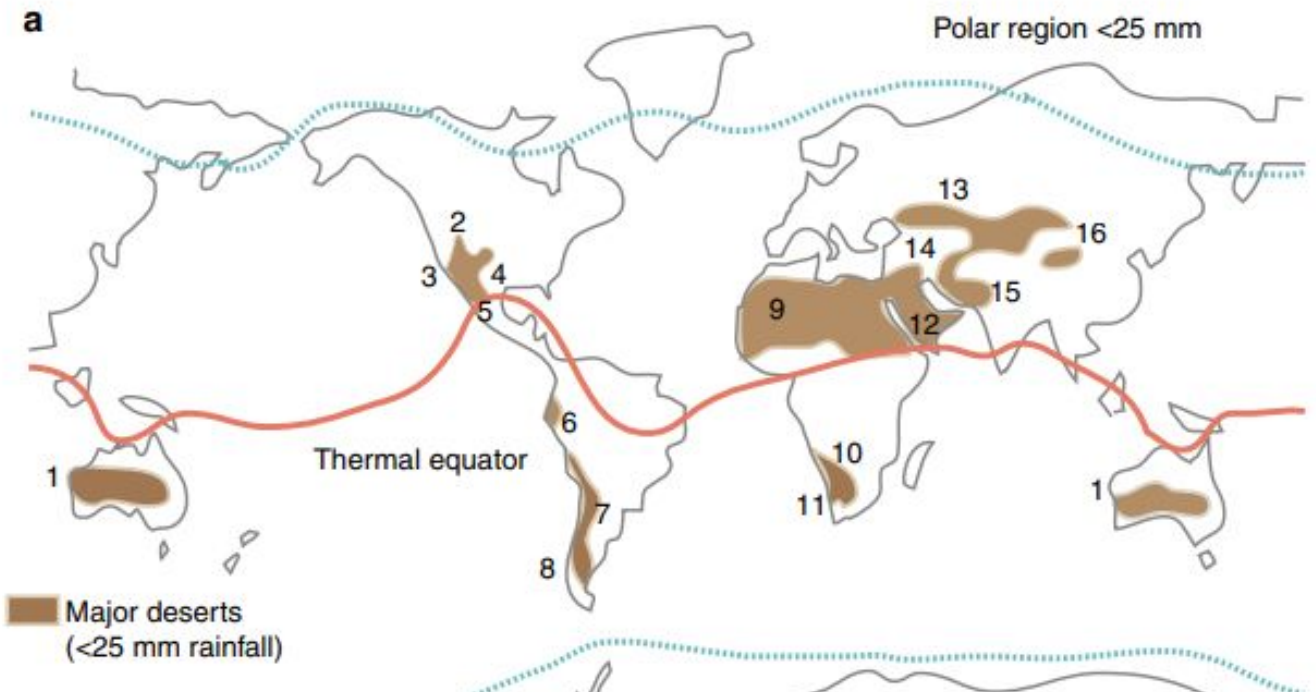
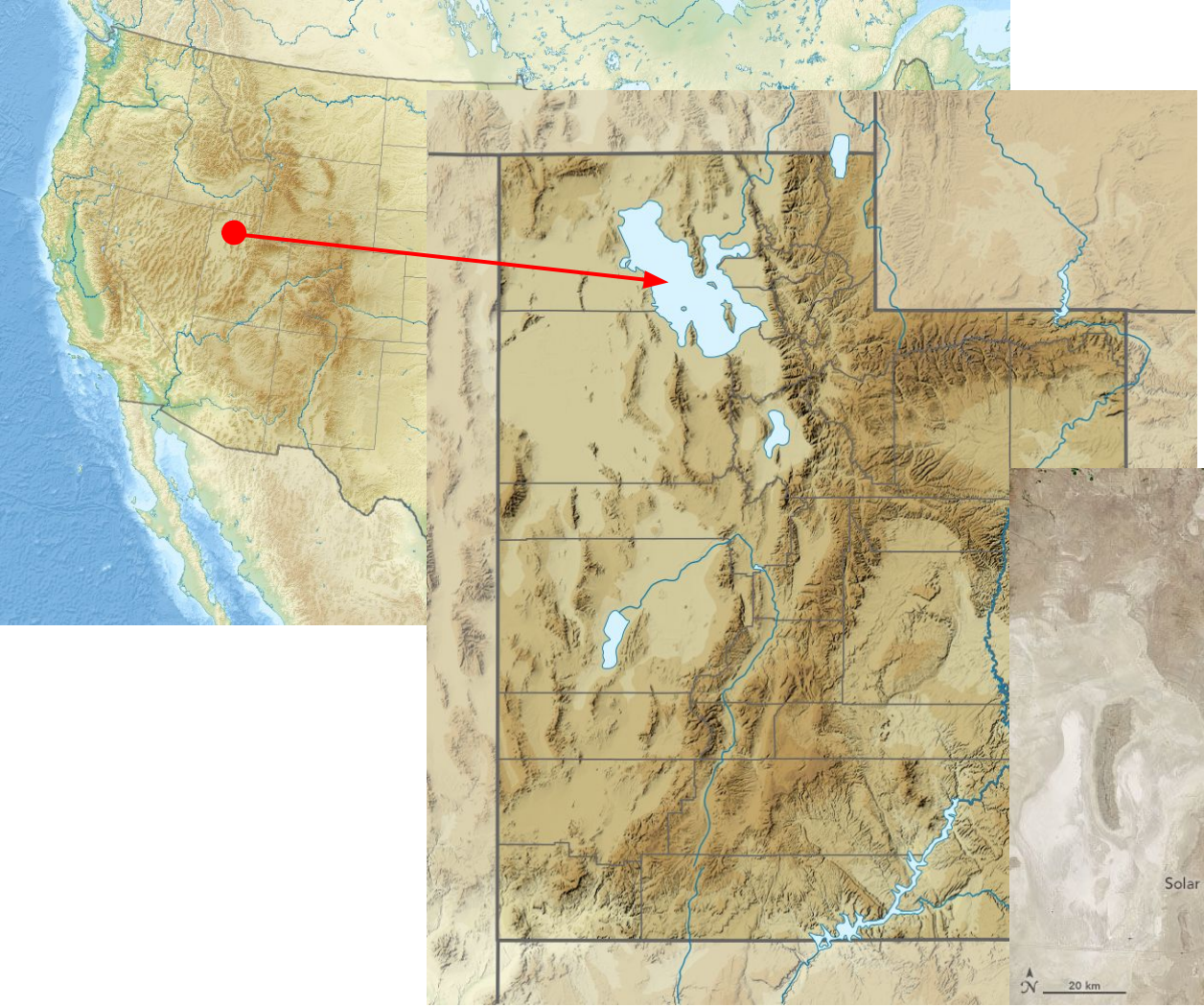


Fig. 2.1 (**a**) World distribution of modern deserts as determined by plotting areas with less than 250 mm annual precipitation. *1*. Australian, *2*. Great Basin, *3*. Mojave (Sonoran), *4*. Chihuahuan, *5*. Baja California, *6*. Peruvian, *7*. Atacama (Chilean), *8*. Patagonian, *9*. Sahara, *10*. Namibian, *11*. Kalahari, *12*. Arabian, *13*. Turkestan, *14*. Iranian, *15*. Thar, *16*. Gobi. Also shows polar regions with less than 25 cm precipitation. Thermal equator joins the points on each line of longitude with the highest annual average temperature (**b**) Latitudinal

Lago salino



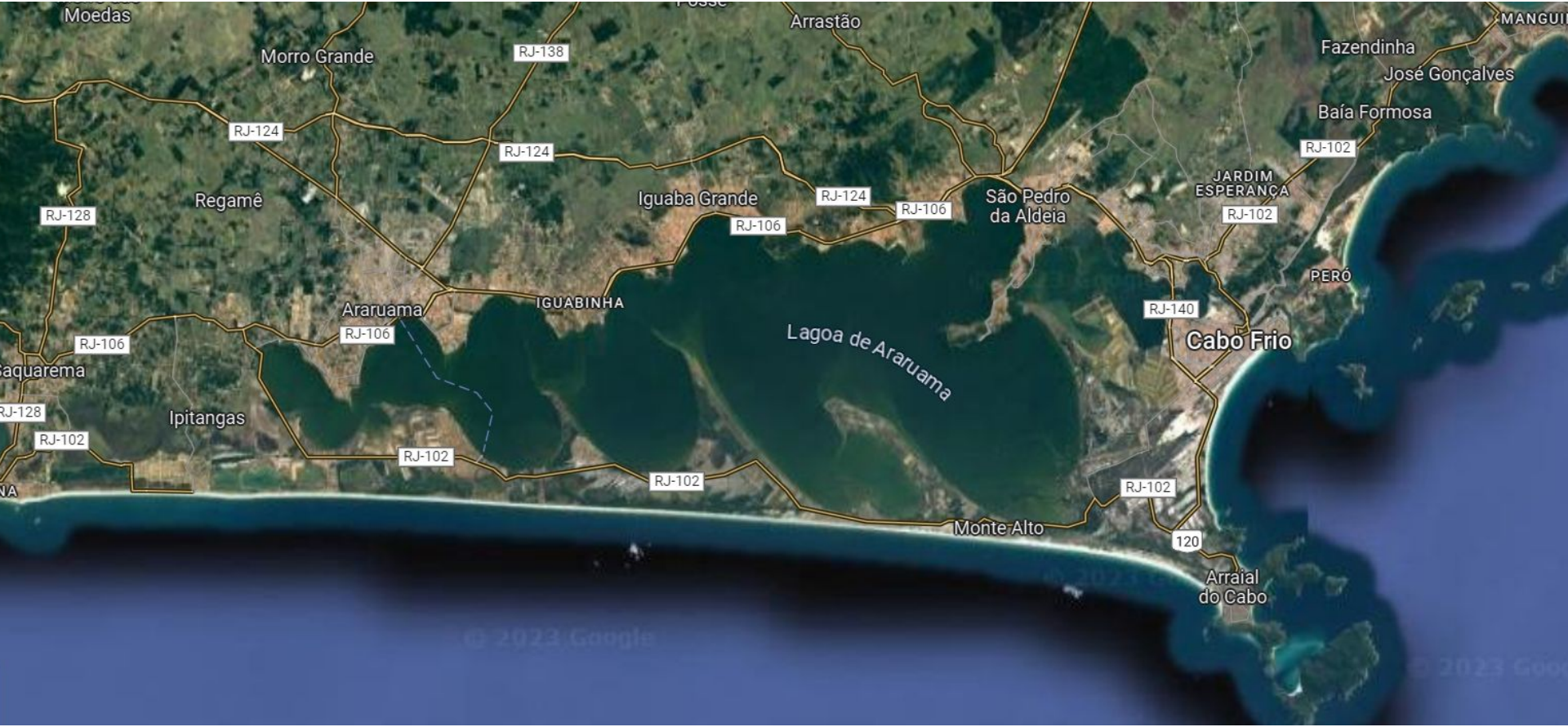
Salinidade varia de 6% a 27%

Salinidade água do mar: 3.5%
Salinidade Mar Morto: 33%

Outros lagos salinos?


Θήρα
Chania
Χανιά
Iráklio
Ηράκλειο
Kriti
Mersin
Chipre
Agia Napa
Αγ. Νάπα
Pafos
Πάφος
Síria
Líbano
Beirute
بيروت
Damasco
دمشق
Haifa
CISJORDÂNIA
erusalém
Berseba
Israel
Jordânia
Aqaba
العقبة
Sharm
el-Sheikh
شرم الشيخ
Tabuk
تبوك
Sacac
سكاكا
King Salman
bin Abdulaziz
Royal Natural
Reserve
محمية الملك
سلمان بن


Dead Sea
Wadi Mu
Arad
Ein Bokek
65
Gawr as-Safi
غور الصافي
Google


Moedas
Morro Grande
RJ-138
Arrastão
Fazendinha
José Gonçalves
Baía Formosa
RJ-124
RJ-124
RJ-102
JARDIM ESPERANÇA
Regamê
RJ-128
Iguaba Grande
RJ-124
RJ-106
São Pedro da Aldeia
RJ-102
RJ-106
PERÓ
IGUABINHA
Araruama
RJ-140
RJ-106
RJ-106
Lagoa de Araruama
Cabo Frio
Saquarema
RJ-128
Ipitangas
RJ-102
RJ-102
RJ-102
RJ-102
Monte Alto
120
Arraial do Cabo
© 2023 Google


Lagoa de Araruama
Refinaria Sal Cisne
SAL CISNE
SAL CISNE
CISNE
Puro bom gosto.

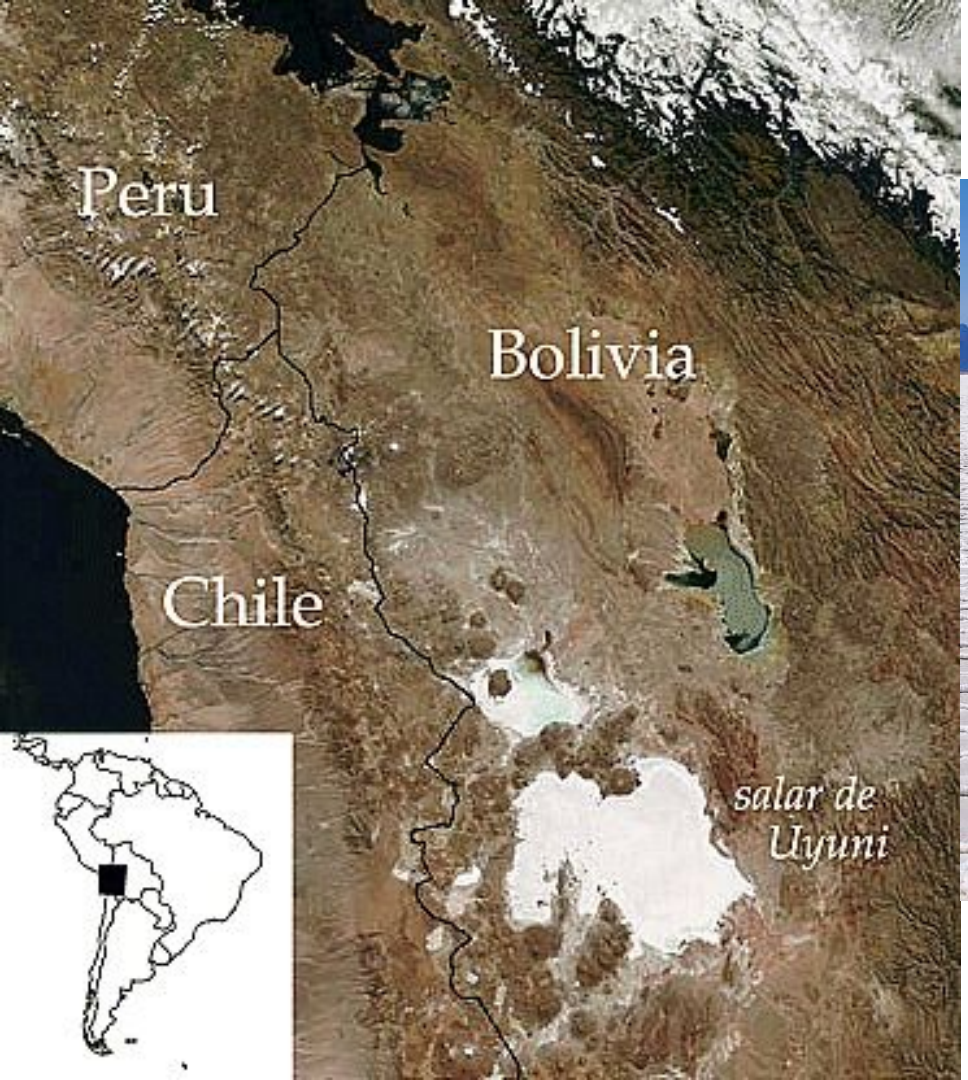

Scablands
Columbia River
Lake Missoula
OR
MT
ID
American Falls Lake
Snake River
Lake Lahontan
Sacramento River
WY
Great Salt Lake
Pacific Ocean
Lake Tahoe
Pyramid Lake
NV
Lake Bonneville
CA
UT
CO
AZ
NM
USA
MEXICO
Present day Lake
Pleistocene Lake
Ice Sheet
Direction of flood
Ice recession
River
Present day coastline

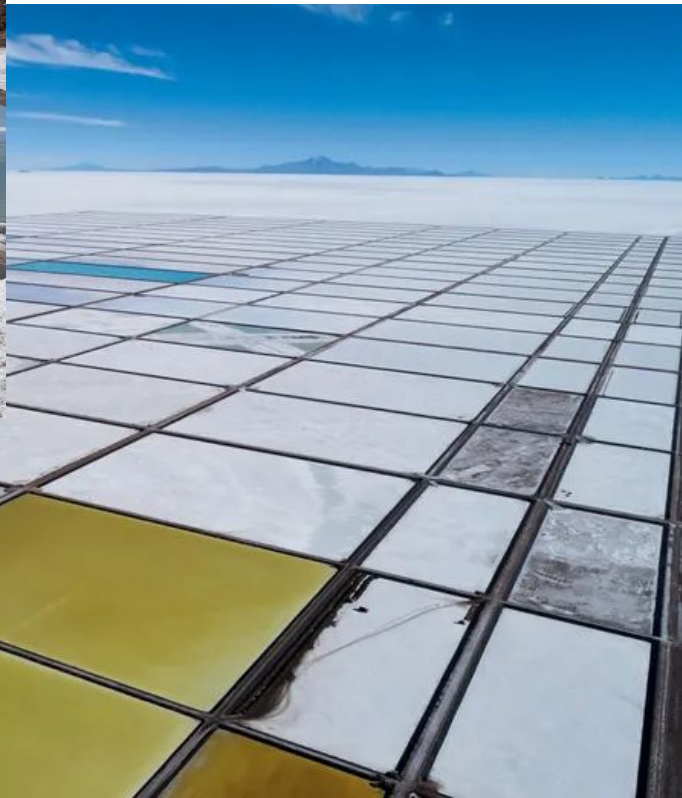
Salt flats

Salt pans

Sabkhas

Outros saltpans, sabkhas?


Peru
Bolivia
Chile
salar de
Uyuni



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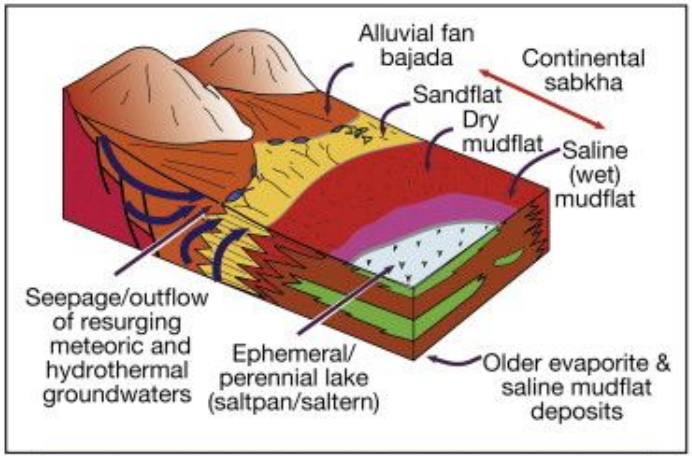

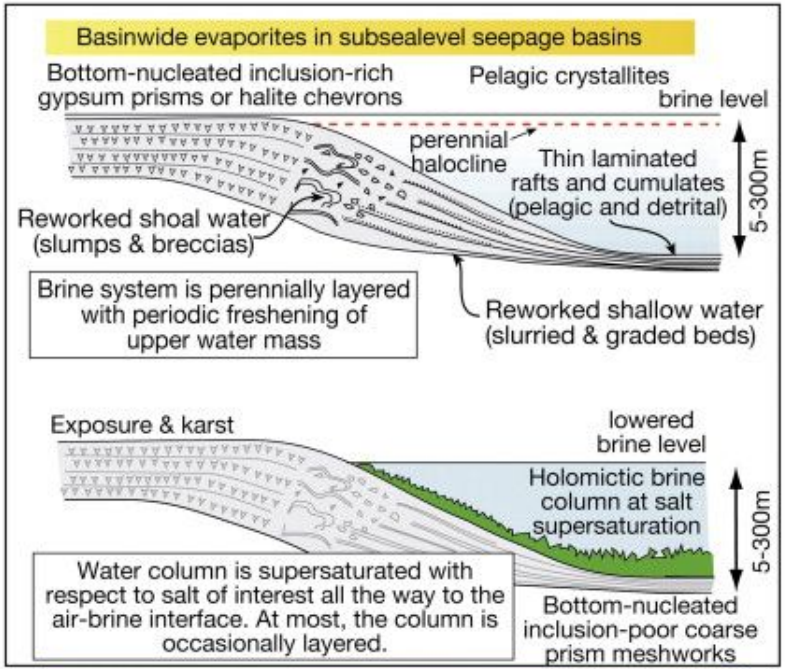

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platform

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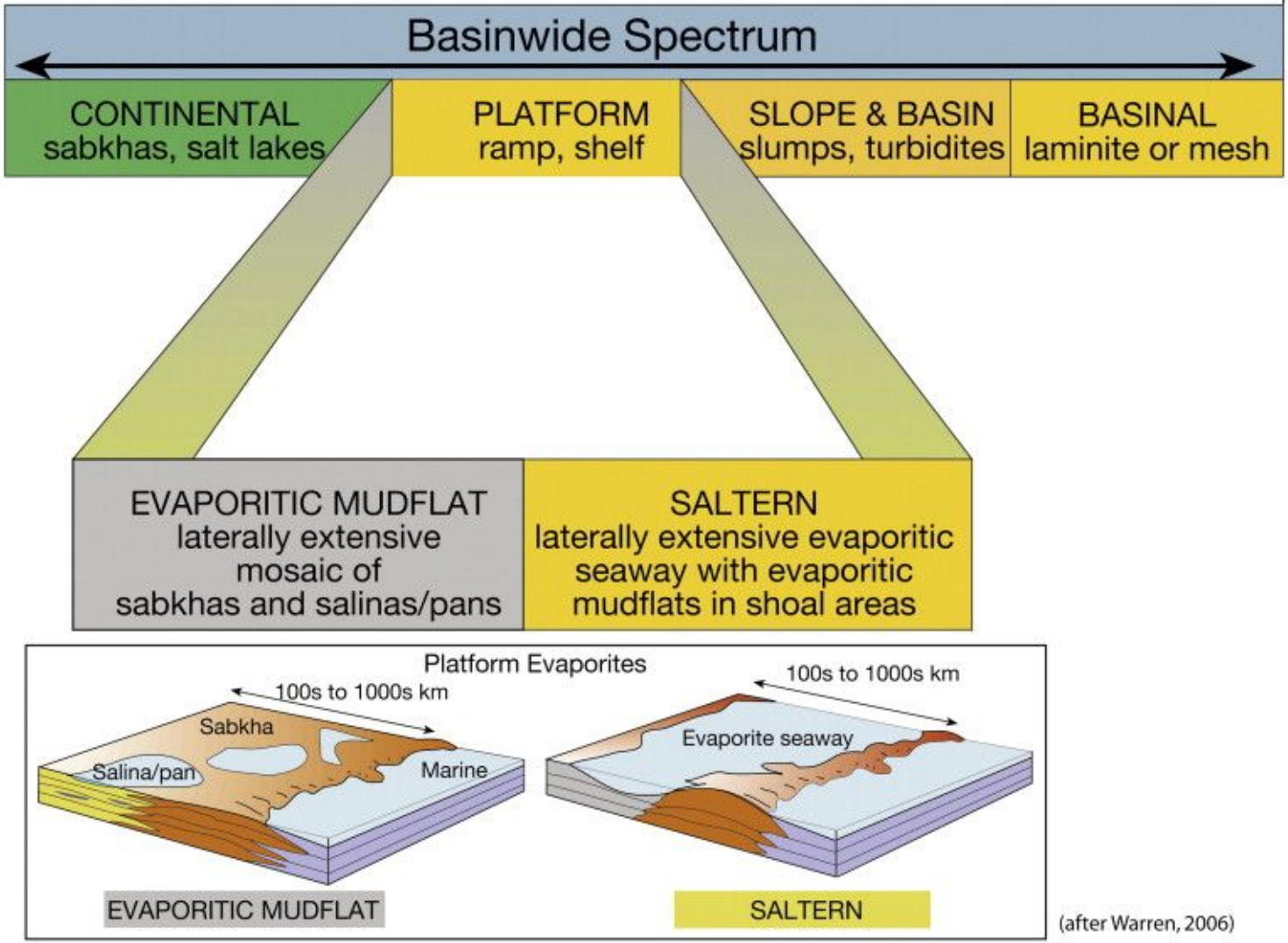
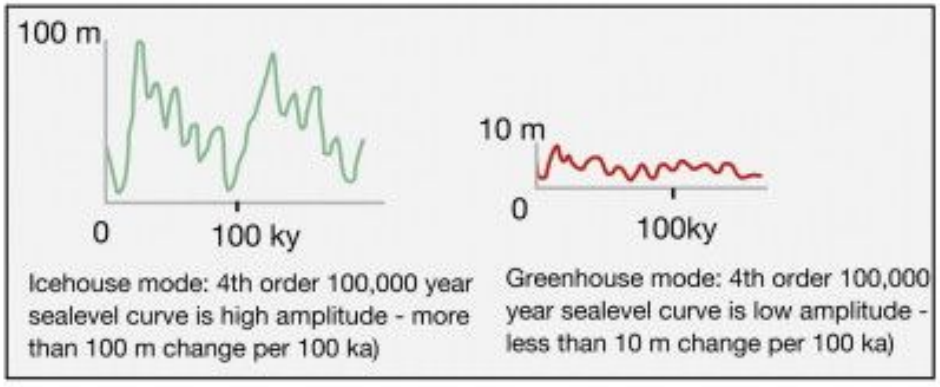
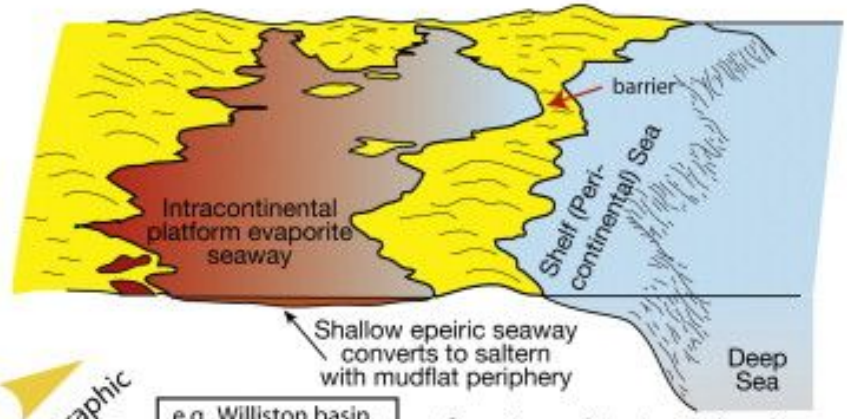


(after Warren, 2006)



Icehouse mode: 4th order 100,000 year sealevel curve is high amplitude - more than 100 m change per 100 ka)

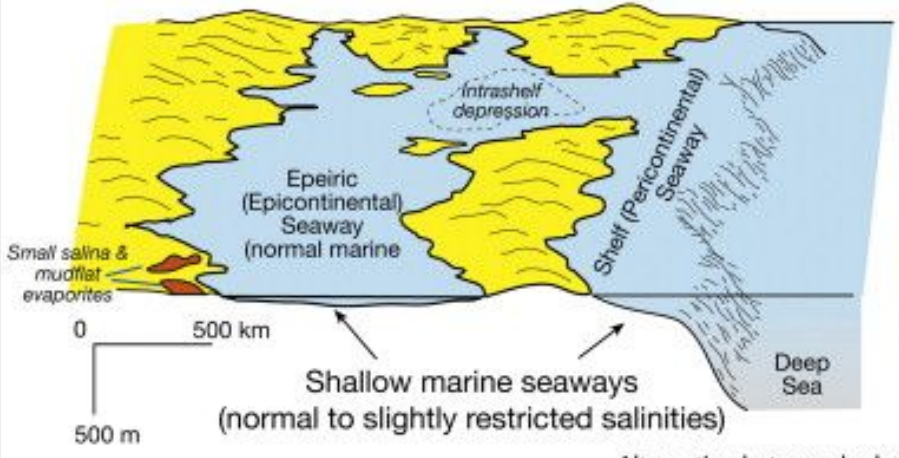
Greenhouse mode: 4th order 100,000 year sealevel curve is low amplitude - less than 10 m change per 100 ka)



Hydrographic isolation

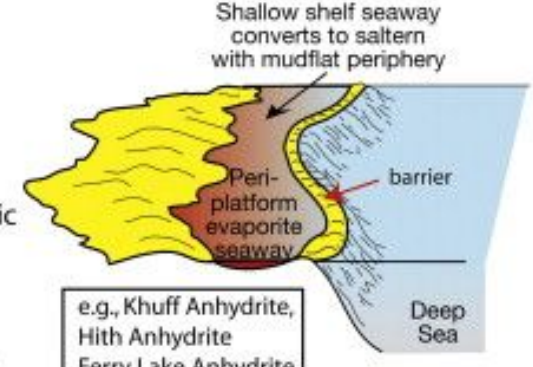
e.g., Williston basin, Michigan Basin, Amazon Basin

Creation of tectonic barrier (greenhouse or icehouse mode)



Shallow marine seaways (normal to slightly restricted salinities)

Hydrographic isolation

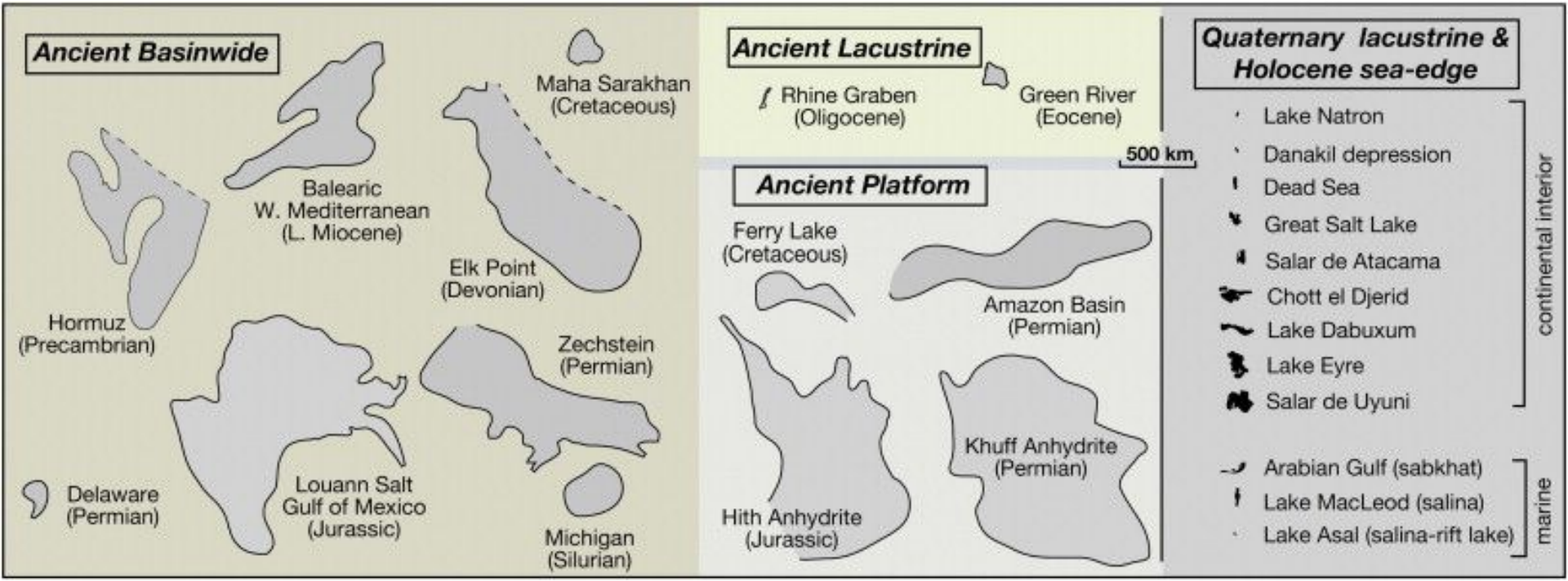


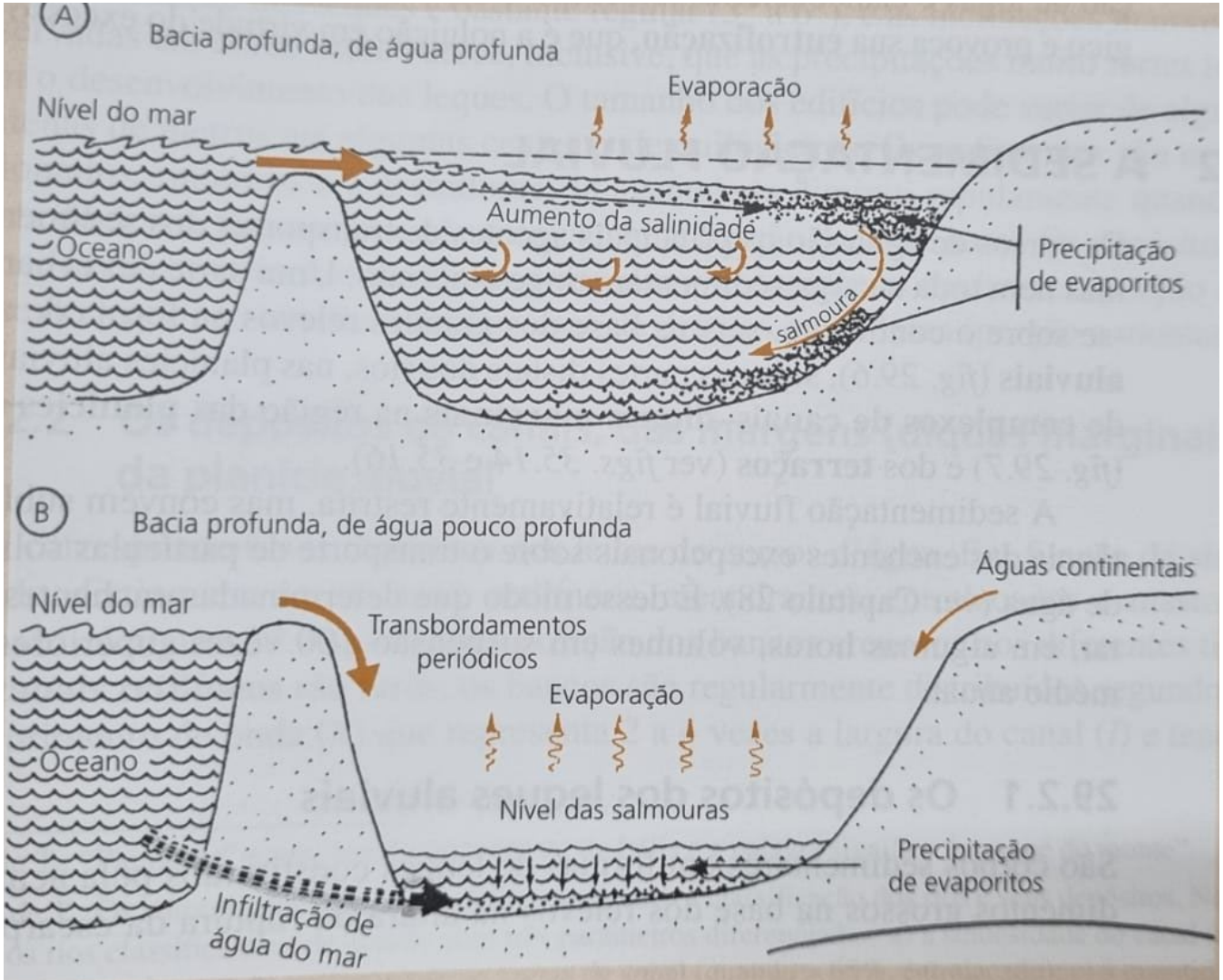
e.g., Khuff Anhydrite, Hith Anhydrite Ferry Lake Anhydrite

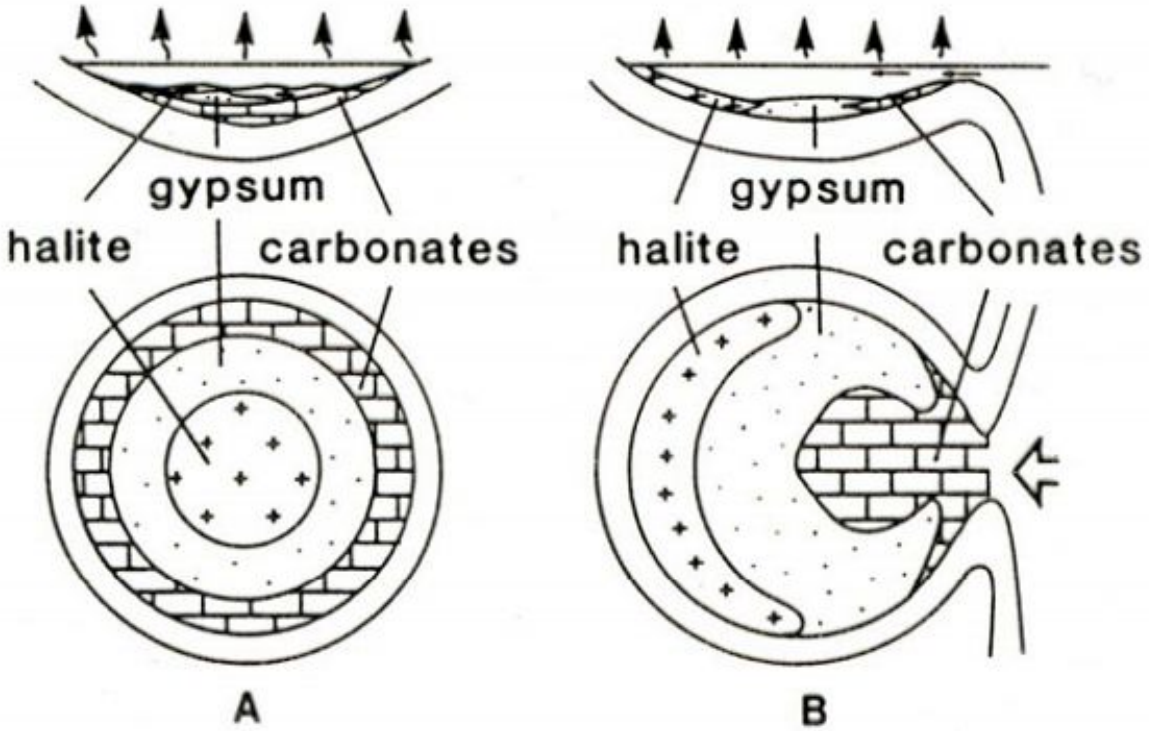
Creation of eustatic barrier (Greenhouse mode)

DEPOSITION OF PLATFORM EVAPORITES

Alternation between hydrographic and nonhydrographic marine connection to depositional basin leads to alternating stacks of marine-carbonate and evaporite beds

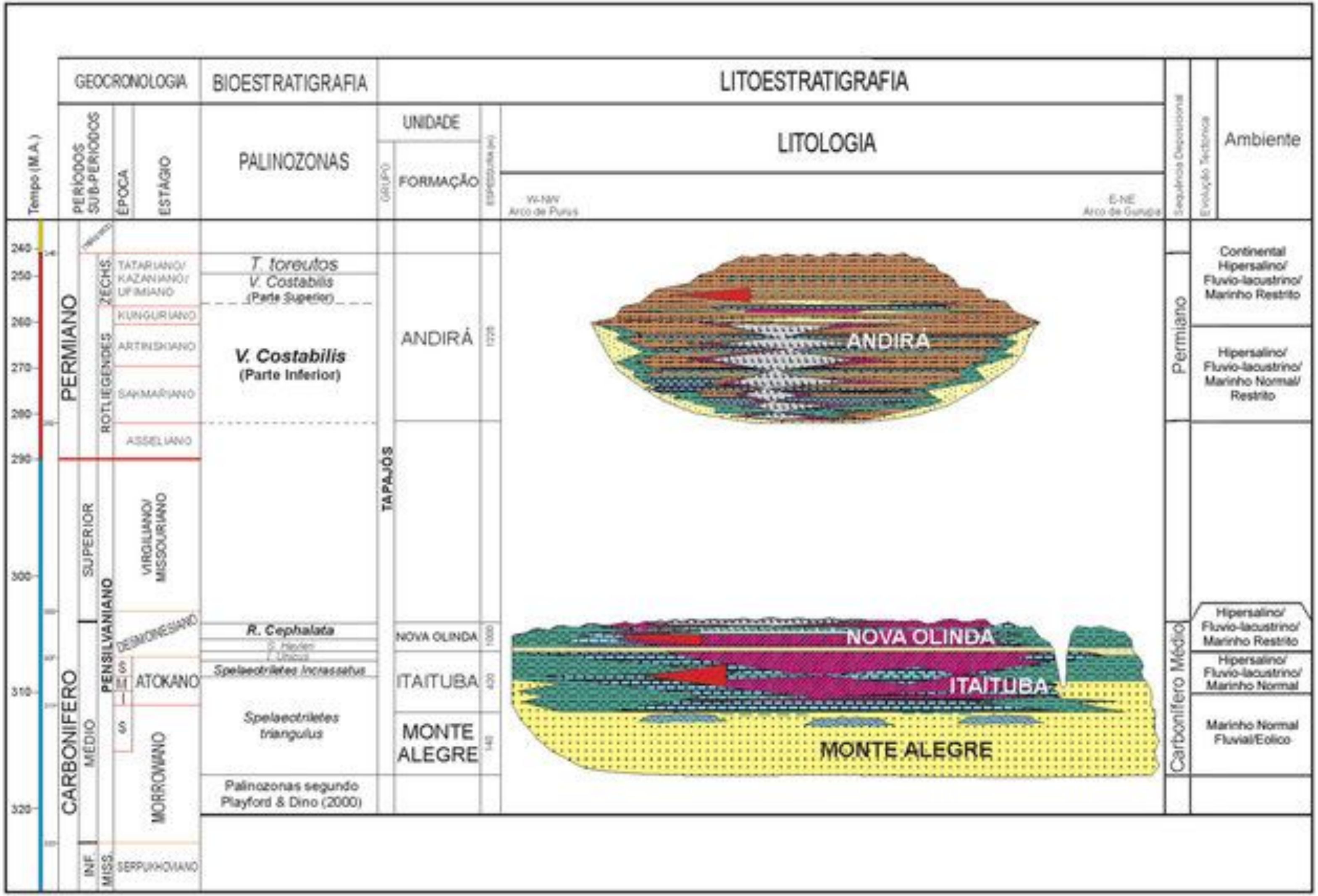

Ancient Basinwide
Maha Sarakhan
(Cretaceous)
Balearic
W. Mediterranean
(L. Miocene)
Elk Point
(Devonian)
Hormuz
(Precambrian)
Zechstein
(Permian)
Delaware
(Permian)
Louann Salt
Gulf of Mexico
(Jurassic)
Michigan
(Silurian)
Ancient Lacustrine
Rhine Graben
(Oligocene)
Green River
(Eocene)
500 km
Ancient Platform
Ferry Lake
(Cretaceous)
Amazon Basin
(Permian)
Khuff Anhydrite
(Permian)
Hith Anhydrite
(Jurassic)
Quaternary lacustrine &
Holocene sea-edge
Lake Natron
Danakil depression
Dead Sea
Great Salt Lake
Salar de Atacama
Chott el Djerid
Lake Dabuxum
Lake Eyre
Salar de Uyuni
continental interior
Arabian Gulf (sabkhat)
Lake MacLeod (salina)
Lake Asal (salina-rift lake)
marine

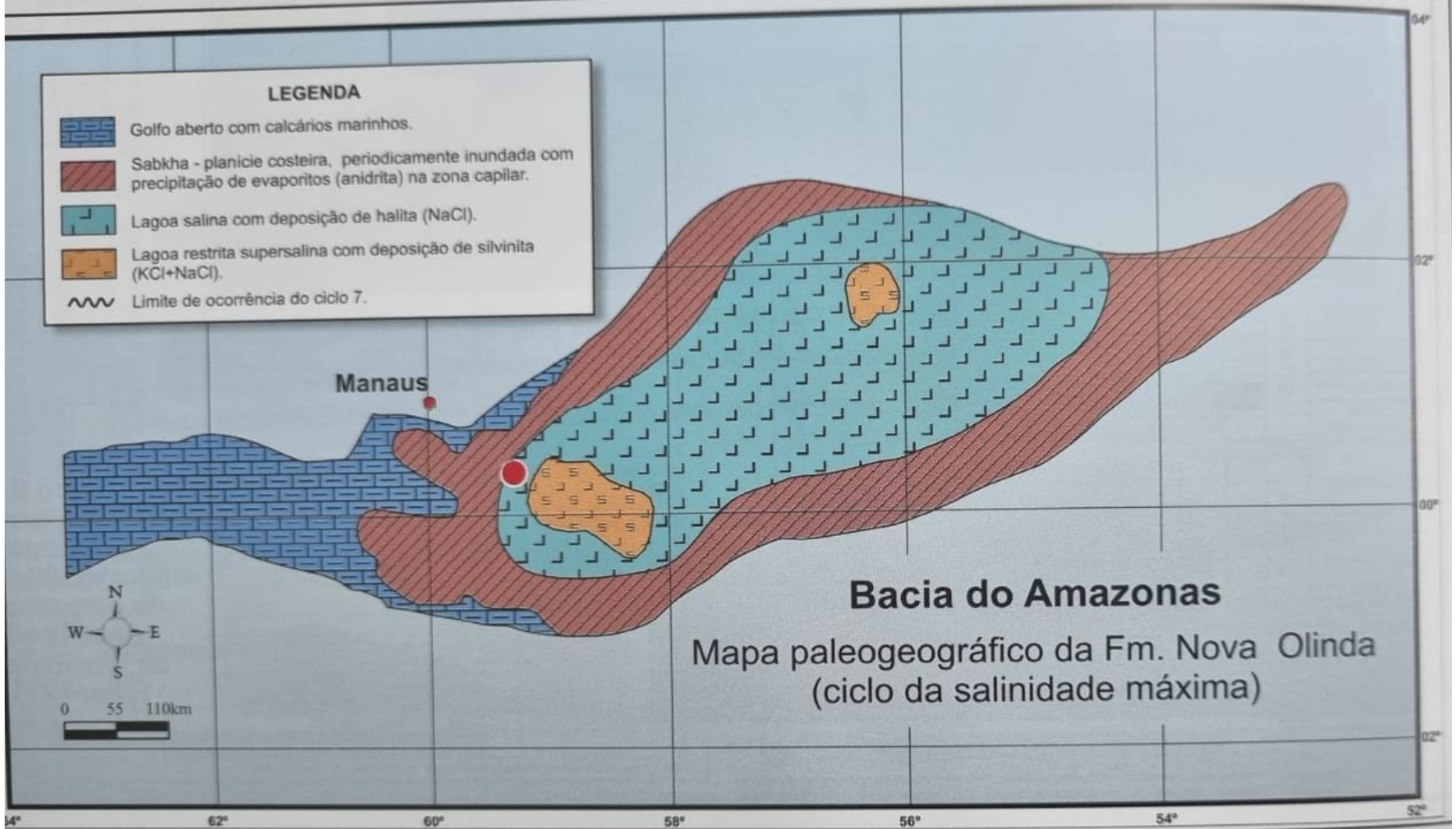

A
Bacia profunda, de água profunda
Nível do mar
Evaporação
Aumento da salinidade
Oceano
Precipitação de evaporitos
Salmoura
B
Bacia profunda, de água pouco profunda
Águas continentais
Nível do mar
Transbordamentos periódicos
Evaporação
Oceano
Nível das salmouras
Precipitação de evaporitos
Infiltração de água do mar



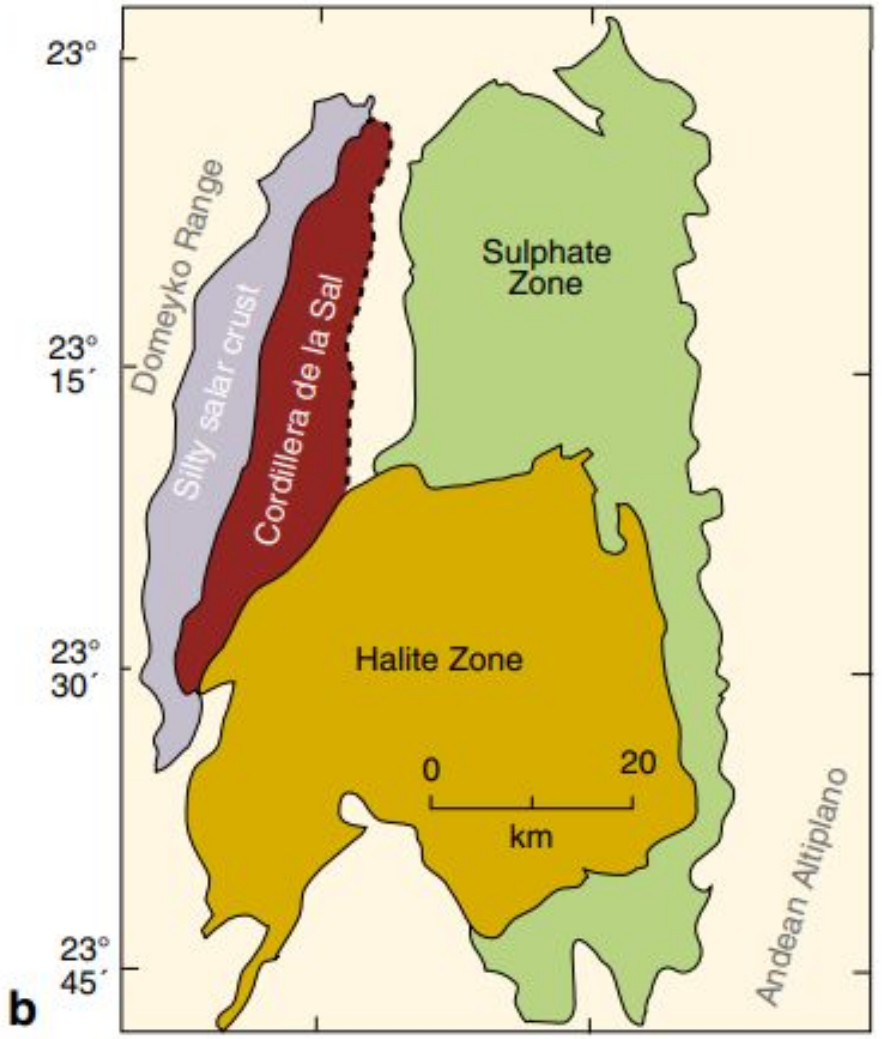
A - Bullseye pattern
most soluble salts in basin center.
Typical of completely enclosed basins

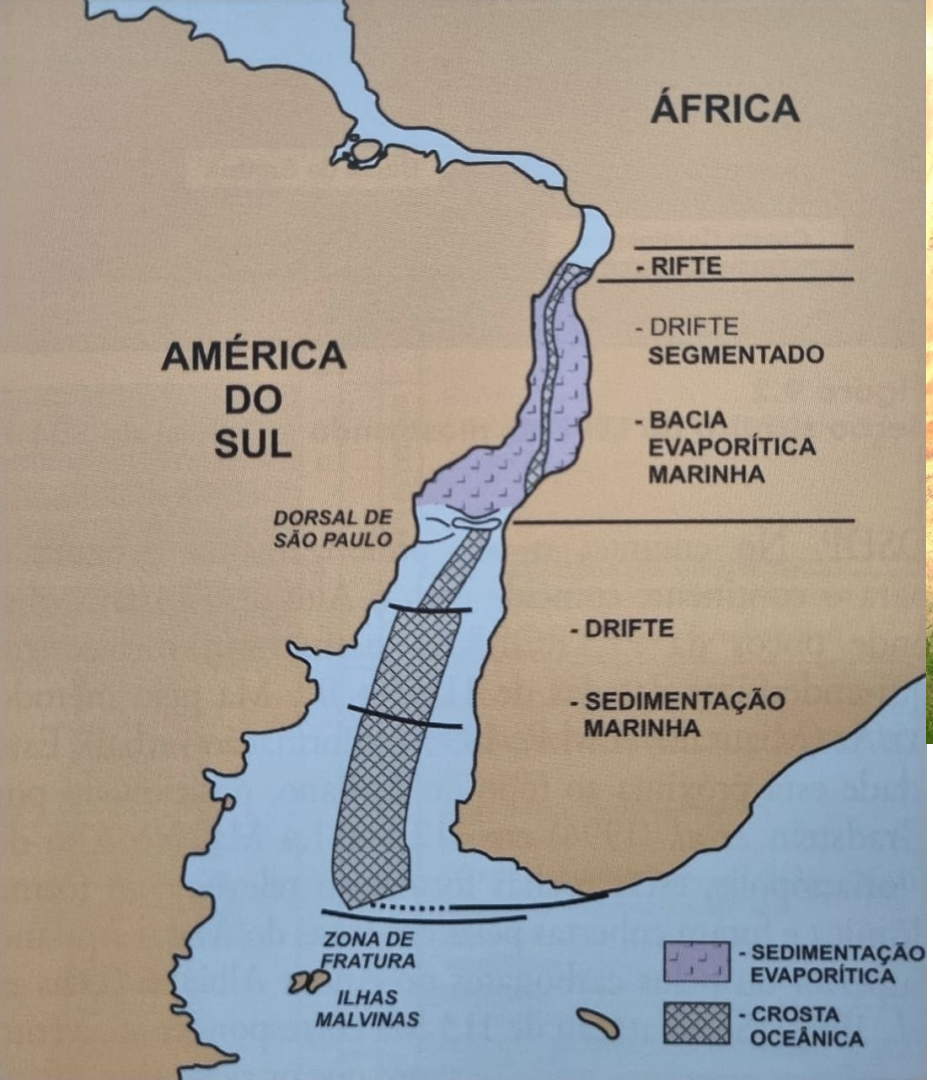
B - Tear-drop pattern
most soluble salts occur away from basin entrance. Typical of restricted basins with near-permanent connection to open ocean

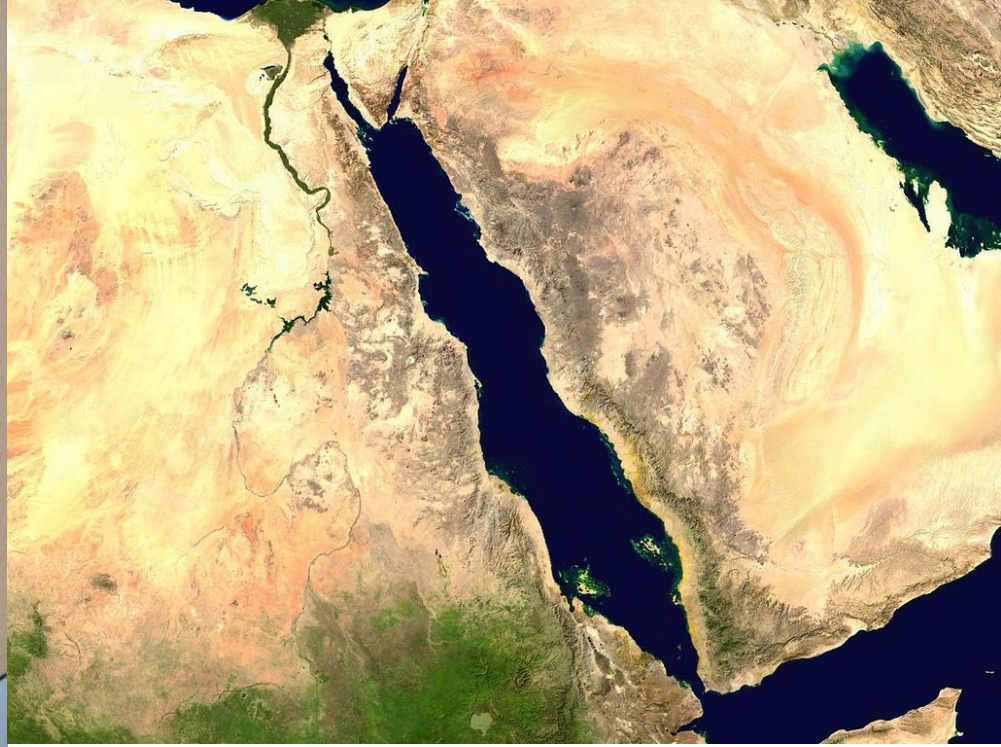

GEOCRONOLOGIA
BIOESTRATIGRAFIA
LITOESTRATIGRAFIA
Tempo (M.A.)
PERÍODOS SUB-PERÍODOS
ÉPOCA
ESTÁGIO
PALINOZONAS
UNIDADE
GRUPO
FORMAÇÃO
LITOLOGIA
W-NW Arco de Purus
E-NE Arco de Gurupá
Sequência Deposicional
Evolução Tectônica
Ambiente
240
250
260
270
280
290
300
310
320
PERMIANO
CARBONÍFERO
SUPERIOR
MÉDIO
INF.
ZECHS
ROTLIEGENDES
PENSILVANIANO
MISS.
TATARIANO/ KAZANIANO/ UFIMIANO
KUNGURIANO
ARTINSKIANO
SAKMARIANO
ASSELIANO
VIRGILIANO/ MISSOURIANO
DESMOINESIANO
ATOKANO
MORROWANO
SERPUKHOVIANO
S
M
I
S
T. toreutos
V. Costabilis (Parte Superior)
V. Costabilis (Parte Inferior)
R. Cephalata
Spelaeotriletes incrassatus
Spelaeotriletes triangulus
Palinozonas segundo Playford & Dino (2000)
TAPAJÓS
ANDIRÁ
NOVA OLINDA
ITAITUBA
MONTE ALEGRE
ANDIRÁ
NOVA OLINDA
ITAITUBA
MONTE ALEGRE
Permiano
Carbonífero Médio
Continental Hipersalino/ Fluvio-lacustrino/ Marinho Restrito
Hipersalino/ Fluvio-lacustrino/ Marinho Normal/ Restrito
Hipersalino/ Fluvio-lacustrino/ Marinho Restrito
Hipersalino/ Fluvio-lacustrino/ Marinho Normal
Marinho Normal Fluvial/Eolico


LEGENDA
Golfo aberto com calcários marinhos.
Sabkha - planicie costeira, periodicamente inundada com precipitação de evaporitos (anidrita) na zona capilar.
Lagoa salina com deposição de halita (NaCl).
Lagoa restrita supersalina com deposição de silvinita (KCl+NaCl).
Limite de ocorrência do ciclo 7.
Manaus
N
W
E
S
0 55 110km
Bacia do Amazonas
Mapa paleogeográfico da Fm. Nova Olinda
(ciclo da salinidade máxima)
04°
02°
00°
02°
64°
62°
60°
58°
56°
54°
52°

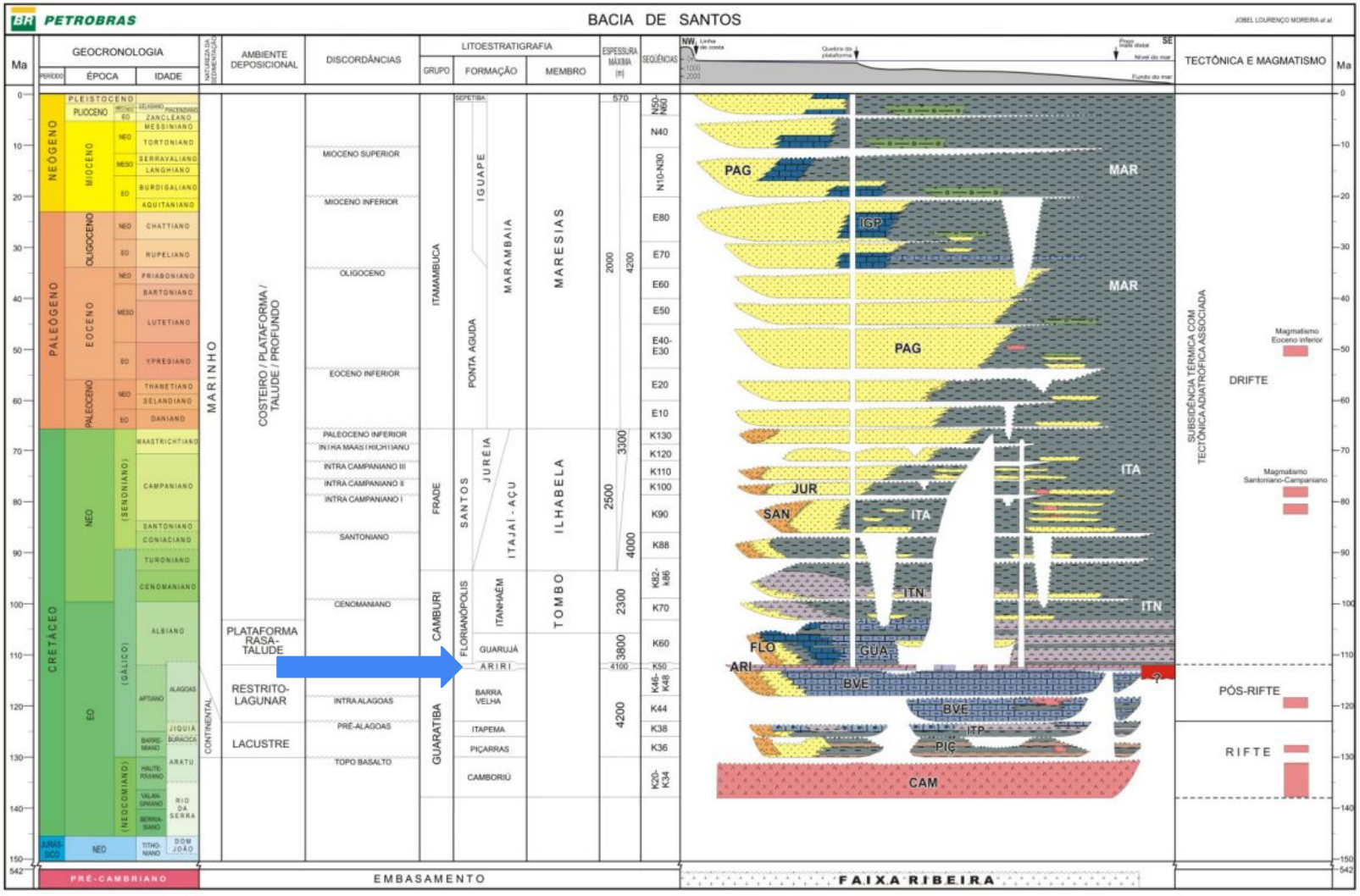

Vilama River
San Pedro River
Llano de la Paciencia salar
Tatio geyser
Solar pans
10 km
a

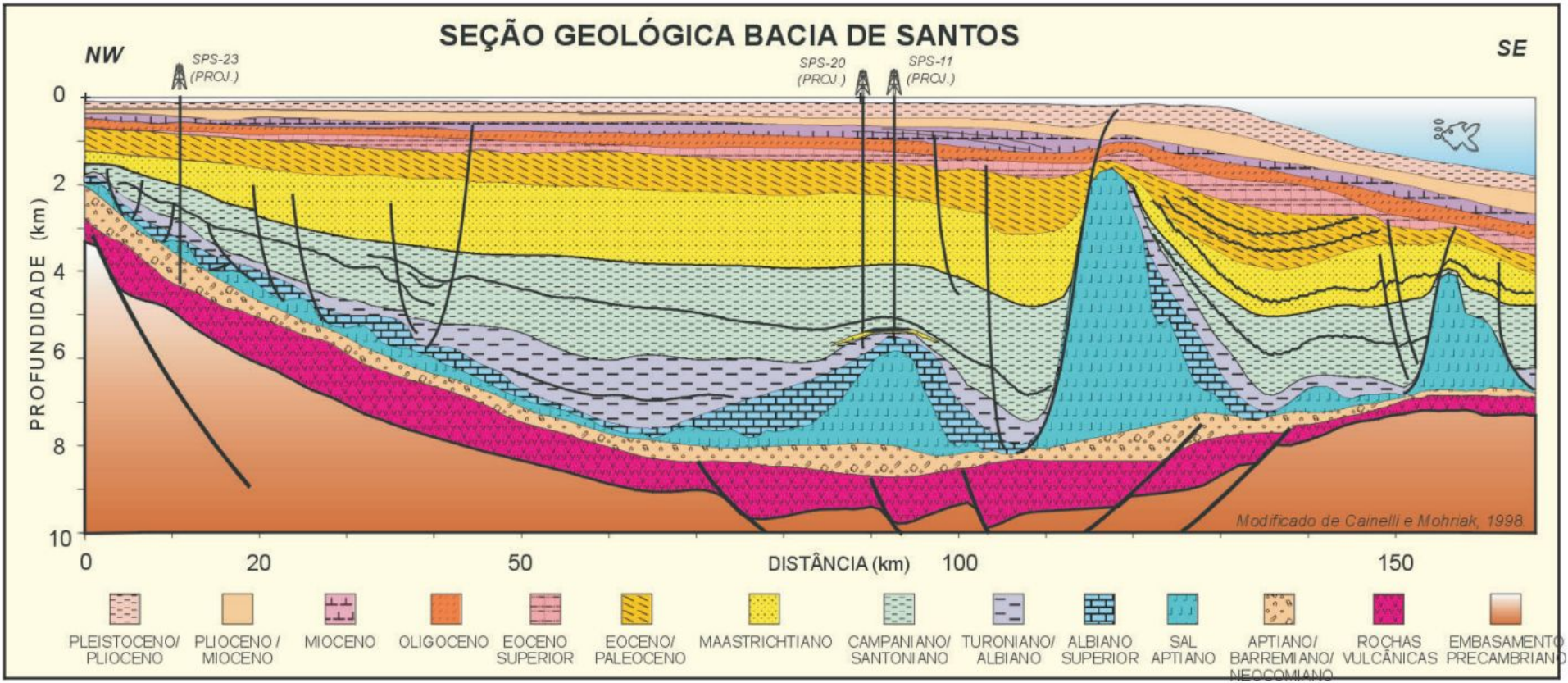

23°
23° 15´
23° 30´
23° 45´
Domeyko Range
Silty salar crust
Cordillera de la Sal
Sulphate Zone
Halite Zone
0
20
km
Andean Altiplano
b





Mar Vermelho

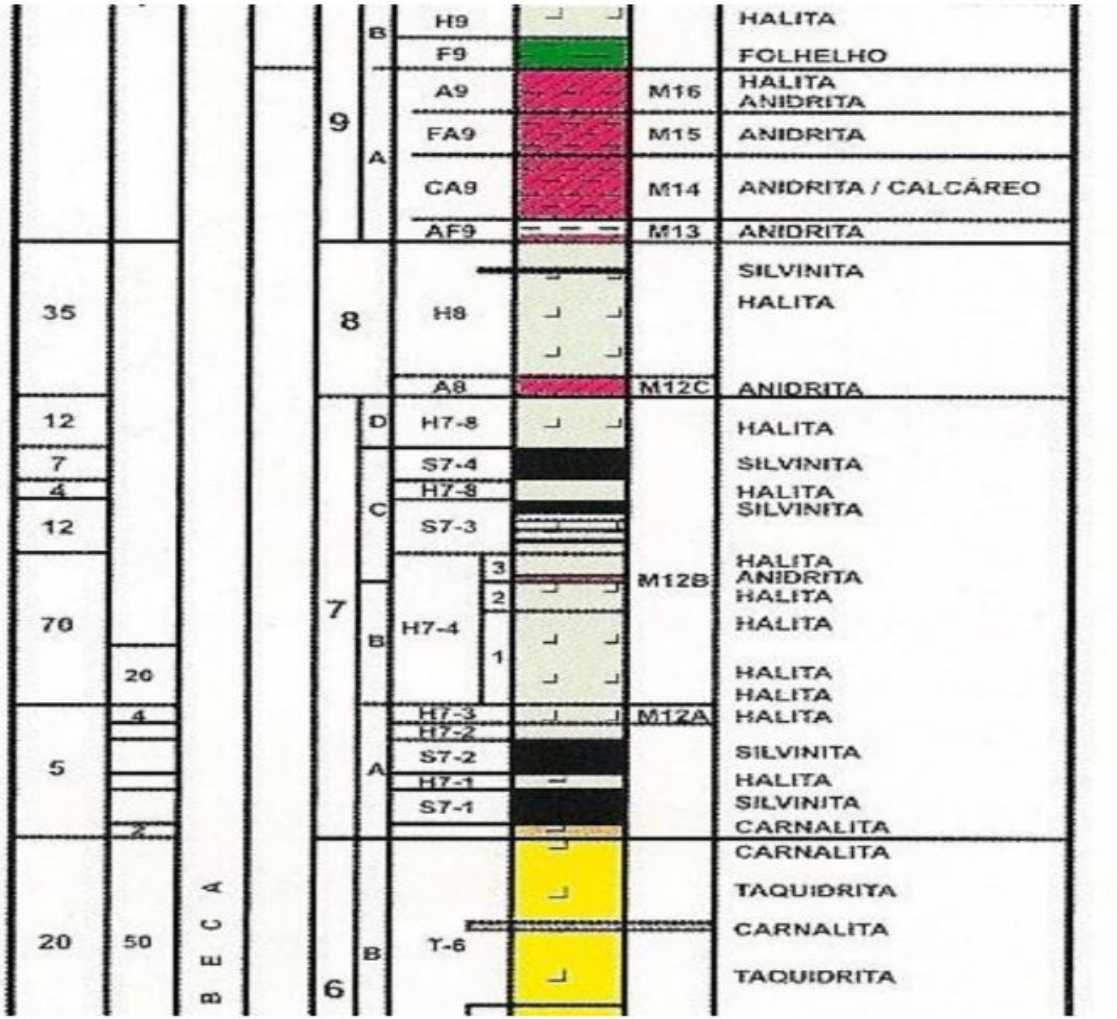

PETROBRAS
BACIA DE SANTOS
JOBEL LOURENÇO MOREIRA et al.
Ma
GEOCRONOLOGIA
PERÍODO
ÉPOCA
IDADE
NATUREZA DA SEDIMENTAÇÃO
AMBIENTE DEPOSICIONAL
DISCORDÂNCIAS
LITOESTRATIGRAFIA
GRUPO
FORMAÇÃO
MEMBRO
ESPESSURA MÁXIMA (m)
SEQÜÊNCIAS
TECTÔNICA E MAGMATISMO
NW
SE
Linha de costa
Quebra da plataforma
Poço mais distal
Nível do mar
Fundo do mar
NEÓGENO
PALEÓGENO
CRETÁCEO
PLEISTOCENO
PLIOCENO
MIOCENO
OLIGOCENO
EOCENO
PALEOCENO
NEO
MESO
EO
PRÉ-CAMBRIANO
MARINHO
CONTINENTAL
COSTEIRO / PLATAFORMA / TALUDE / PROFUNDO
PLATAFORMA RASA-TALUDE
RESTRITO-LAGUNAR
LACUSTRE
MIOCENO SUPERIOR
MIOCENO INFERIOR
OLIGOCENO
EOCENO INFERIOR
PALEOCENO INFERIOR
INTRA MAASTRICHTIANO
INTRA CAMPANIANO III
INTRA CAMPANIANO II
INTRA CAMPANIANO I
SANTONIANO
CENOMANIANO
INTRA ALAGOAS
PRÉ-ALAGOAS
TOPO BASALTO
ITAMAMBUCA
FRADE
CAMBURI
GUARATIBA
SEPETIBA
IGUAPE
PONTA AGUDA
MARAMBAIA
SANTOS
JUREIA
ITAJAÍ-AÇU
FLORIANÓPOLIS
ITANHAÉM
GUARUJÁ
ARIRI
BARRA VELHA
ITAPEMA
PIÇARRAS
CAMBORIÚ
MARESIAS
TOMBO
ILHABELA
2000
4200
2500
3300
4000
2300
3800
4100
4200
PAG
MAR
IGP
PAG
MAR
JUR
SAN
ITA
ITA
ITN
ITN
FLO
GUA
ARI
BVE
BVE
ITP
PIÇ
CAM
?
SUBSIDÊNCIA TÉRMICA COM TECTÔNICA ADIATRÓFICA ASSOCIADA
Magmatismo Eoceno Inferior
DRIFTE
Magmatismo Santoniano-Campaniano
PÓS-RIFTE
RIFTE
EMBASAMENTO
FAIXA RIBEIRA



Halita + Anidrita

Bacia de Sergipe-Alagoas
Formação Iburá

Halita (NaCl)
Silvita (KCl)
Taquidrita ($2(MgCl).CaCl_2.12H_2O$)
Carnalita ($KCl.MgCl_2.6H_2O$)



Machado & Mohriak (2008)

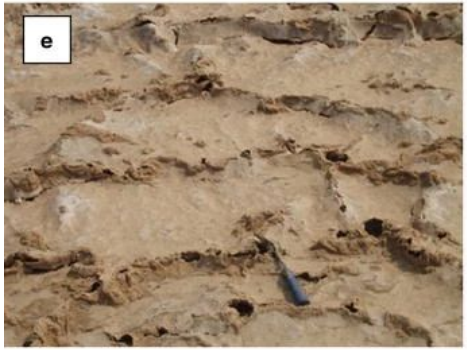
Estruturas sedimentares

Domos em gipsita

- Formados a partir da pressão exercida por escape de gases abaixo do tapete microbial
- Tapete microbial impede a troca gasosa entre o sedimento e a atmosfera/água
- A pressão exercida pelo gás levanta o tapete microbial
- Gipsita cristaliza na superfície do domo levantado devido à evaporação da água

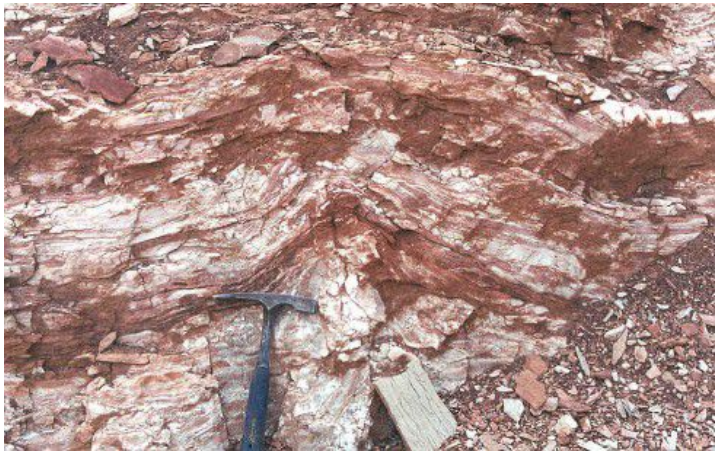

c


d


e


g


f

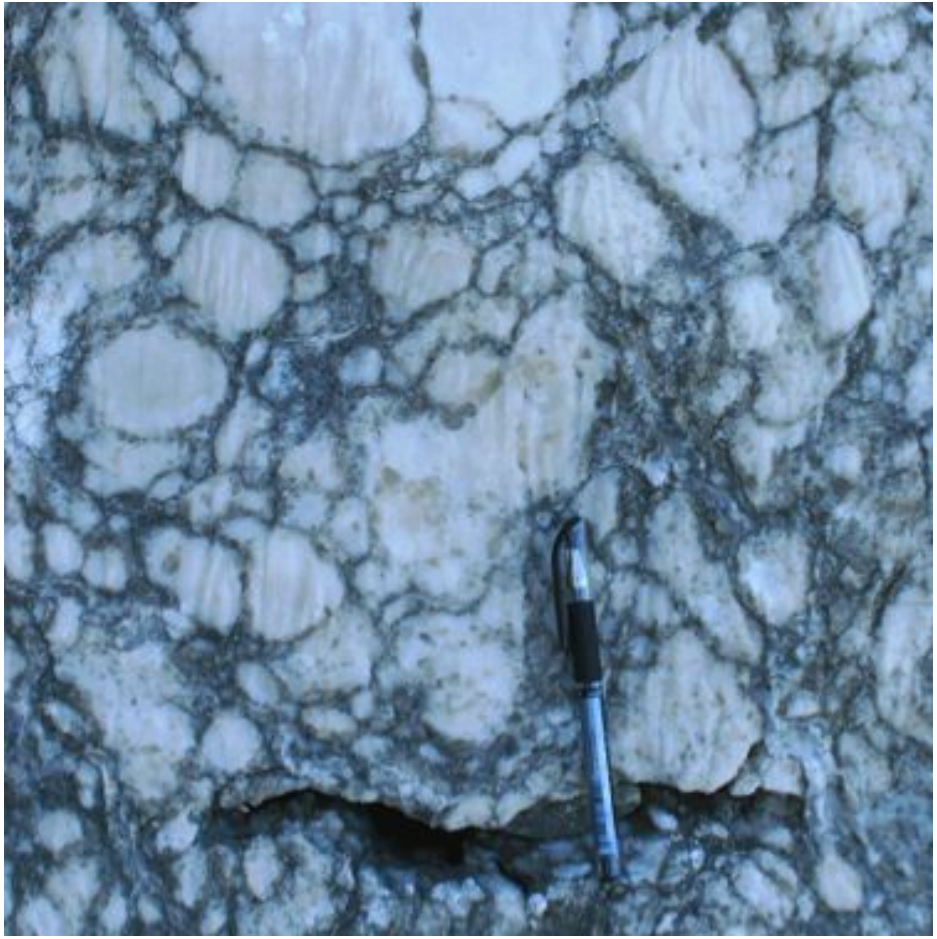


Teepee

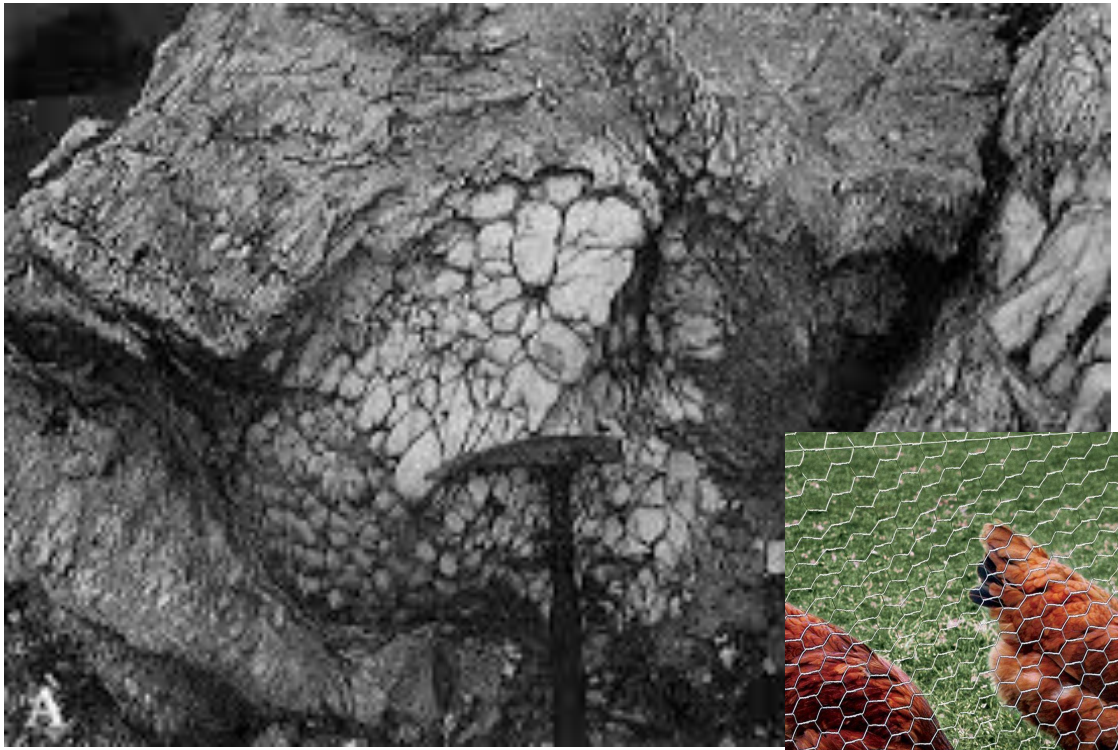
Petee

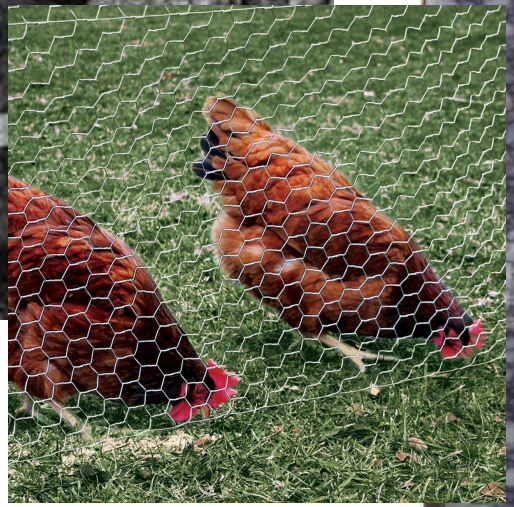
Crostas com dobras poligonais

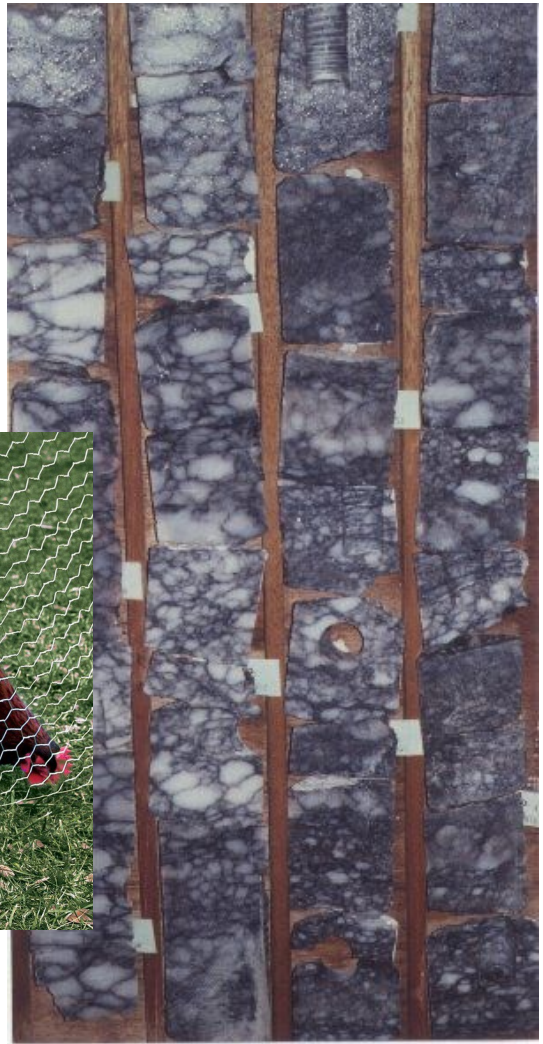
Gretas poligonais



Anidrita nodular

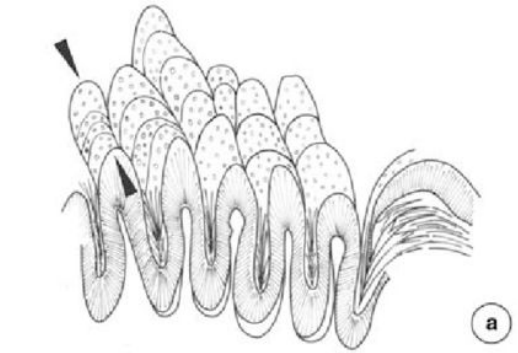


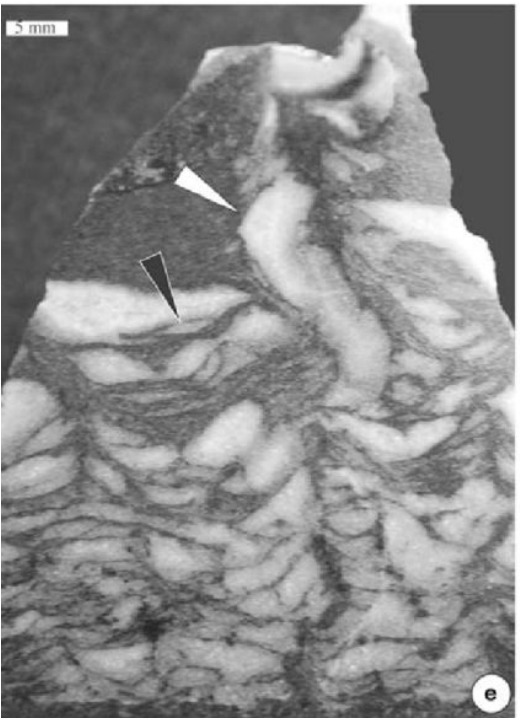


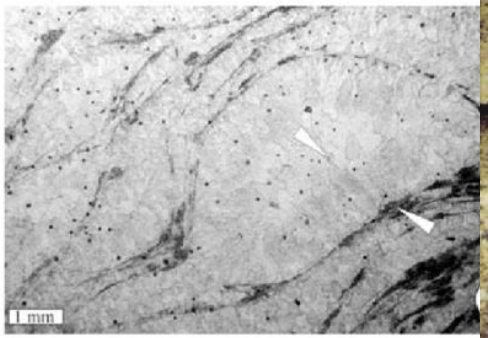


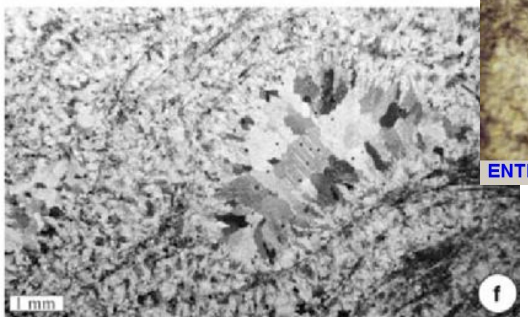
Anidrita nodular - ‘chicken wire’

Dobras enterolíticas

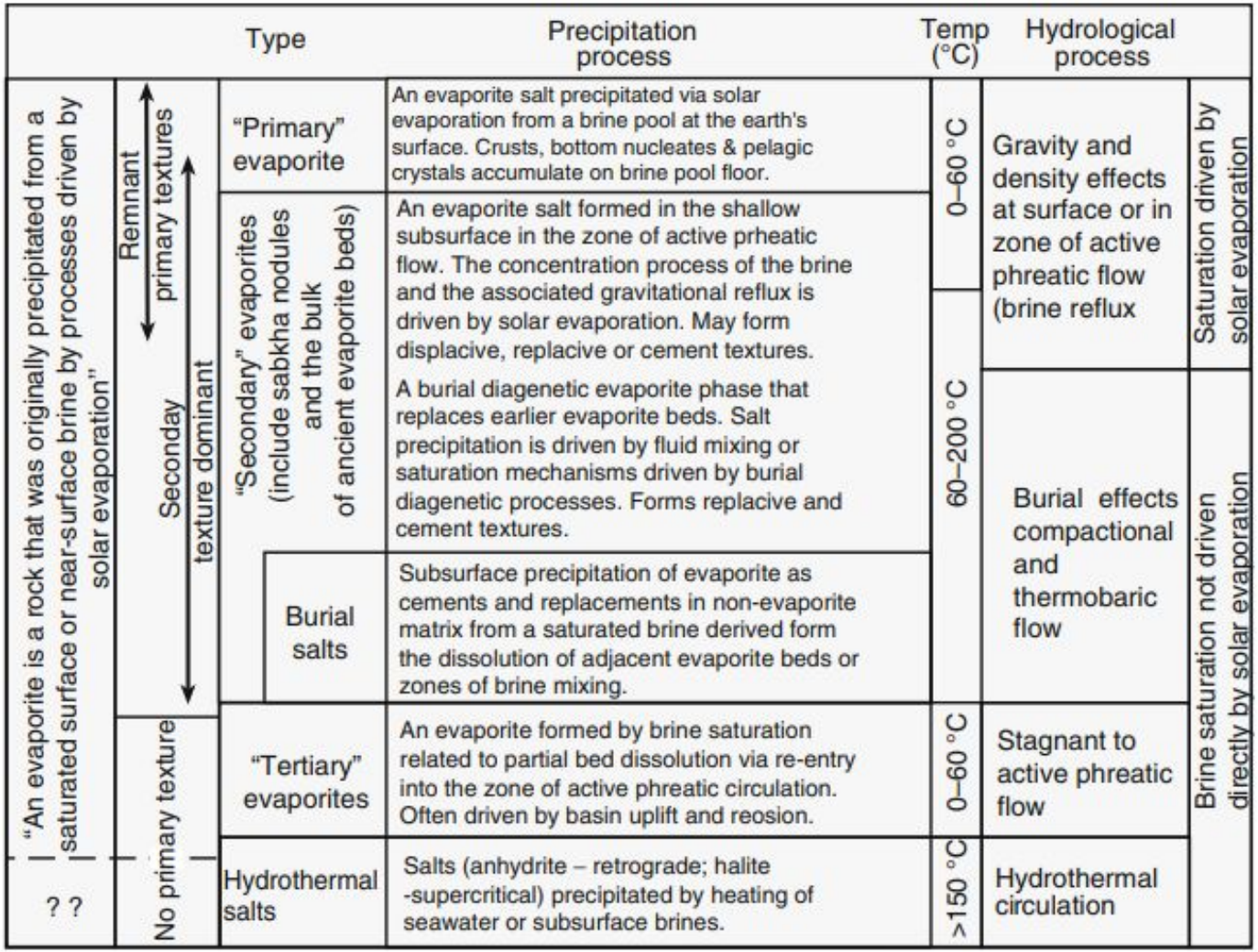








ENTEROLITHIC VEINS AND NODULES OF GYPSUM, IN A SABKHA NEAR EL ALAMEIN, EGYPT.


Type
Precipitation process
Temp (°C)
Hydrological process
"An evaporite is a rock that was originally precipitated from a saturated surface or near-surface brine by processes driven by solar evaporation"
Remnant primary textures
Seconday texture dominant
No primary texture
? ?
"Primary" evaporite
An evaporite salt precipitated via solar evaporation from a brine pool at the earth's surface. Crusts, bottom nucleates & pelagic crystals accumulate on brine pool floor.
0–60 °C
Gravity and density effects at surface or in zone of active phreatic flow (brine reflux
Saturation driven by solar evaporation
"Secondary" evaporites (include sabkha nodules and the bulk of ancient evaporite beds)
An evaporite salt formed in the shallow subsurface in the zone of active prheatic flow. The concentration process of the brine and the associated gravitational reflux is driven by solar evaporation. May form displacive, replacive or cement textures.
A burial diagenetic evaporite phase that replaces earlier evaporite beds. Salt precipitation is driven by fluid mixing or saturation mechanisms driven by burial diagenetic processes. Forms replacive and cement textures.
60–200 °C
Burial effects compactional and thermobaric flow
Brine saturation not driven directly by solar evaporation
Burial salts
Subsurface precipitation of evaporite as cements and replacements in non-evaporite matrix from a saturated brine derived form the dissolution of adjacent evaporite beds or zones of brine mixing.
"Tertiary" evaporites
An evaporite formed by brine saturation related to partial bed dissolution via re-entry into the zone of active phreatic circulation. Often driven by basin uplift and reosion.
0–60 °C
Stagnant to active phreatic flow
Hydrothermal salts
Salts (anhydrite – retrograde; halite -supercritical) precipitated by heating of seawater or subsurface brines.
>150 °C
Hydrothermal circulation

EXERCÍCIO 1

EXERCÍCIO 2