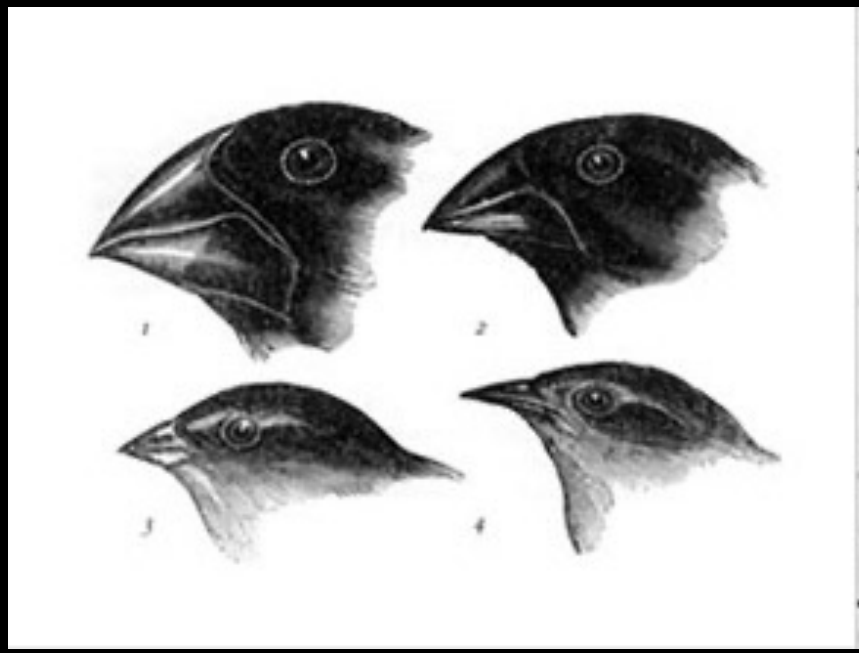
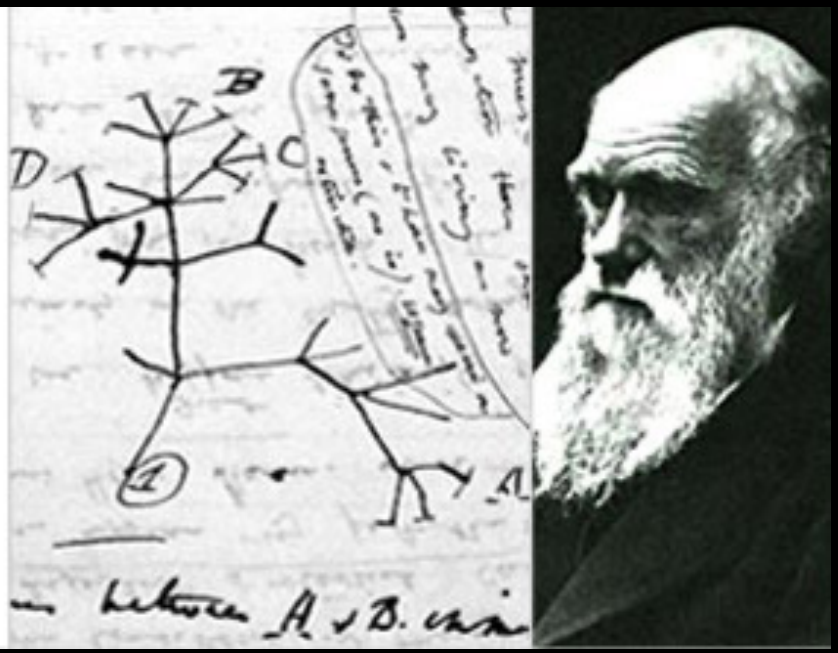
Biogeografia

Biogeografia

Definições





Definições

Biogeografia

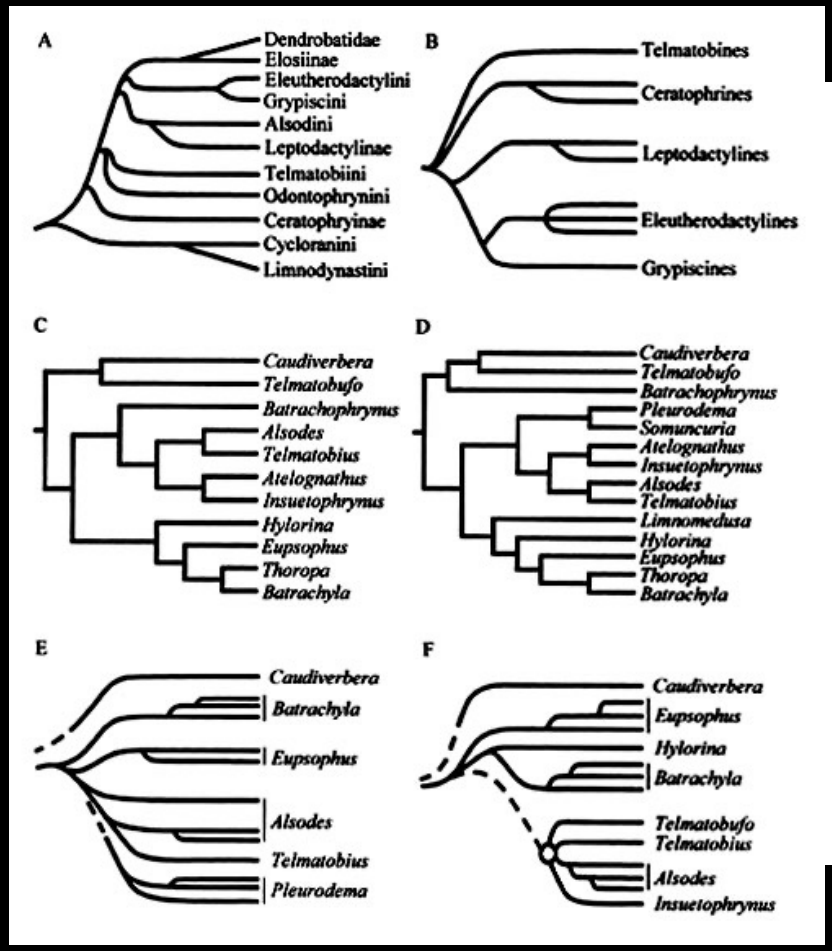
-Estudo da distribuição geográfica dos organismos (Myers & Giller)

-Estudo dos organismos no espaço e no tempo (Cox & Moore)

- documentar e entender padrões espaciais de diversidade biológica; o estudo da distribuição dos organismos no passado e no presente (Lomolino et al.)

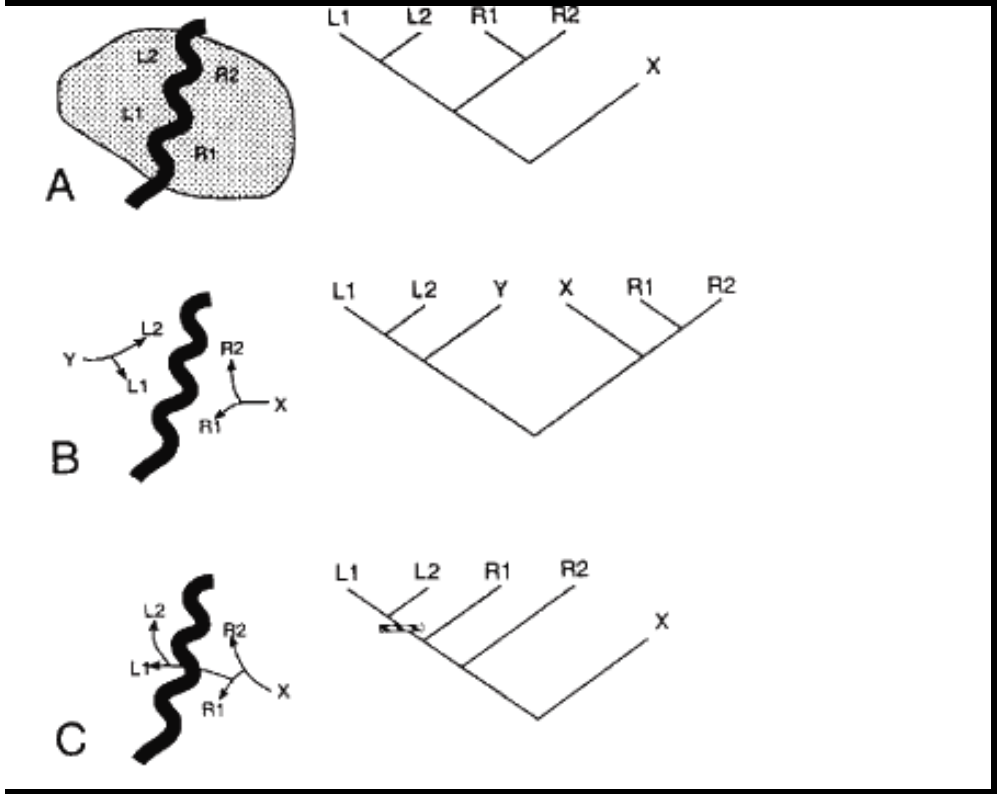
Como a diversidade biológica varia ao longo da geografia?

Definições



Padrões

Filogenéticos, distribuição



Processos

Especiação, deriva continental

Diversidade biológica

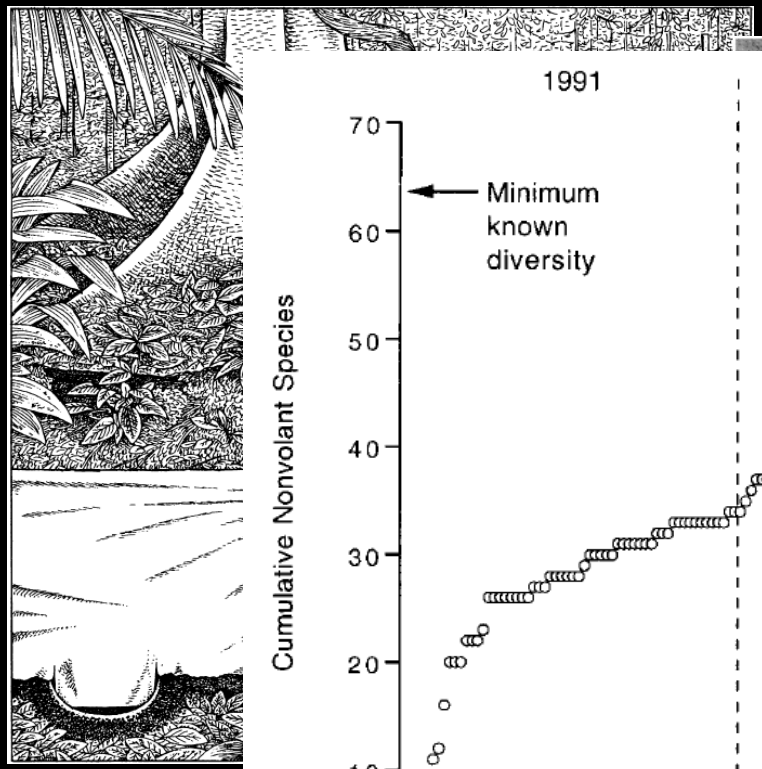
Riqueza de espécies

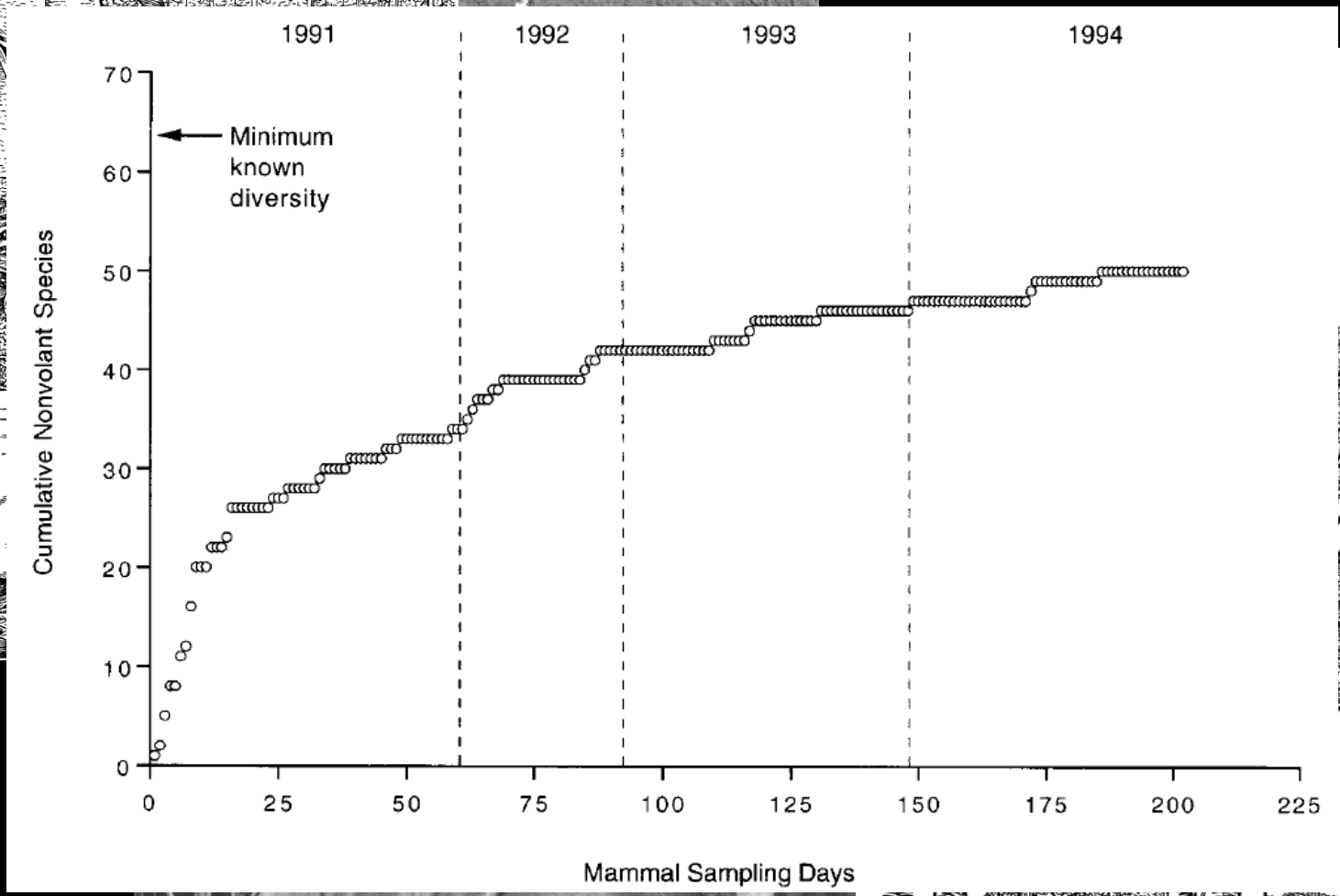
Acervos

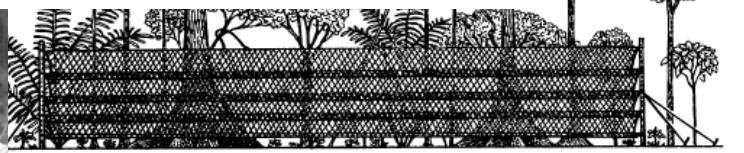
Diversidade biológica

Riqueza de espécies

Inventários

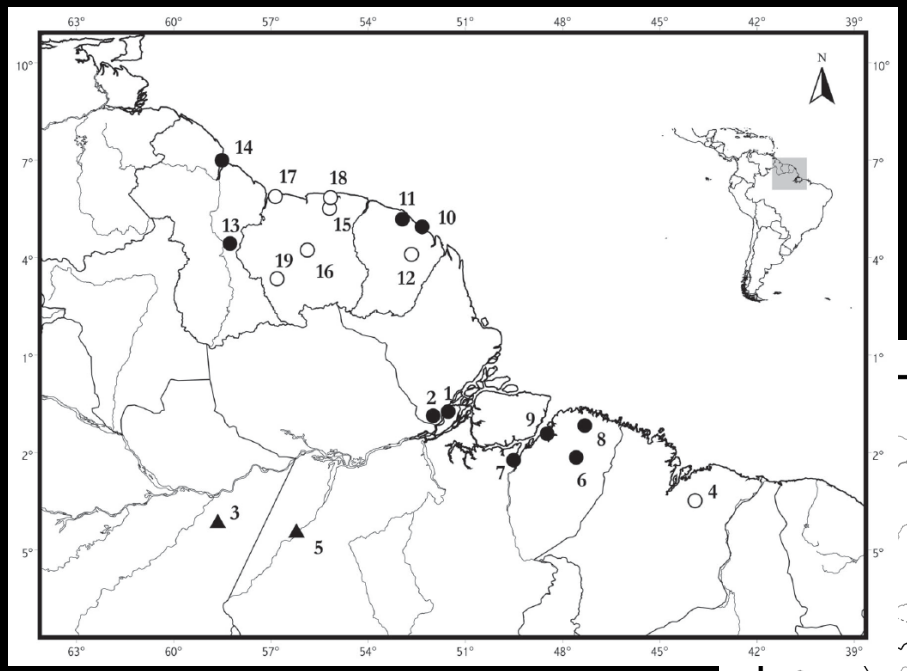


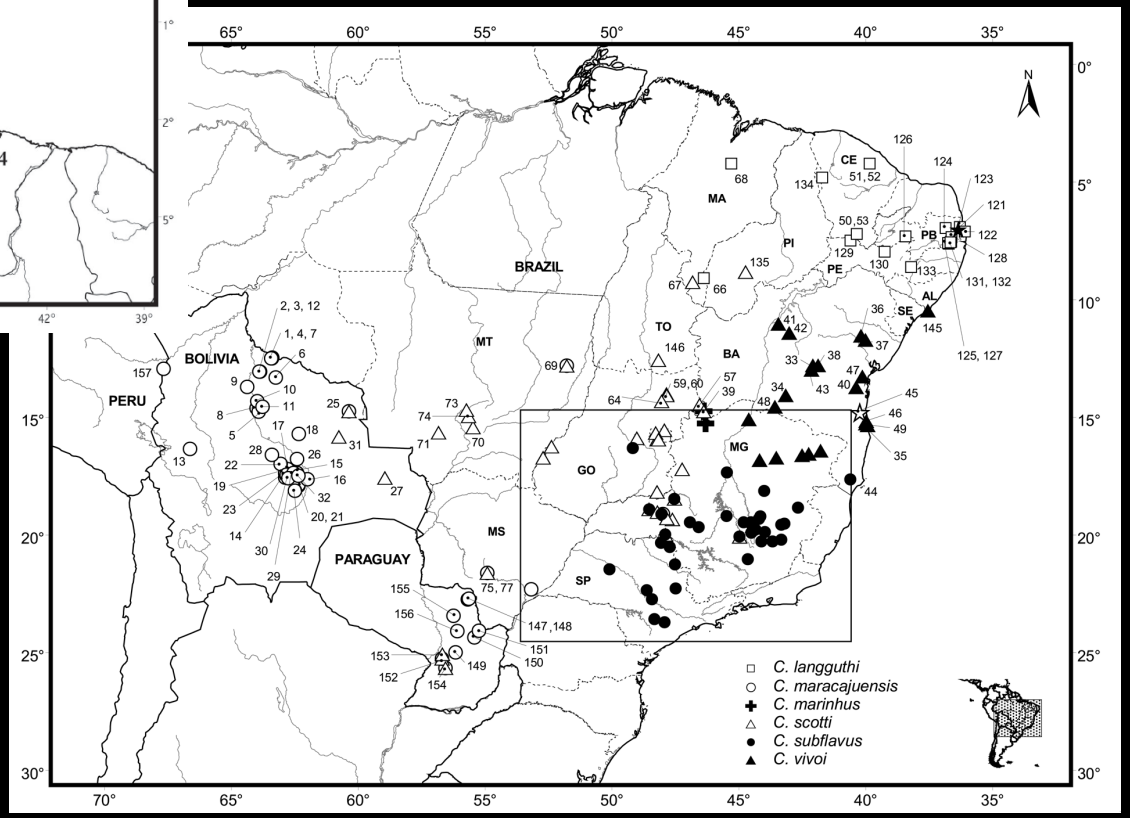




Diversidade biológica

Distribuição geográfica





Espécies X Geografia

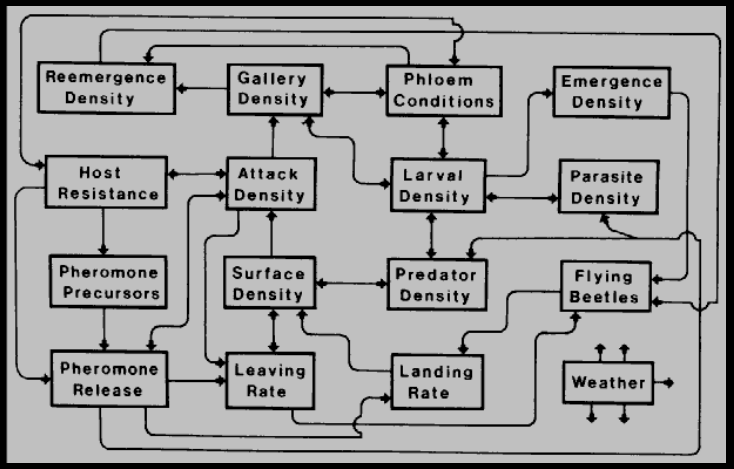
Relações Evolutivas e Ecológicas

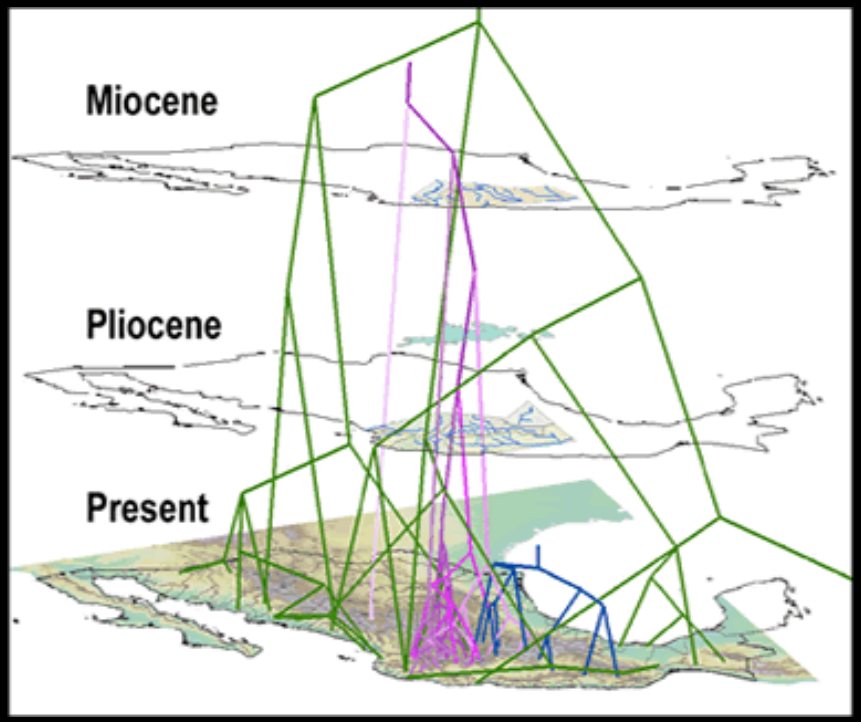
Biogeografia Histórica

origem, vicariância, dispersão, extinção

Biogeografia Ecológica

interações organismos X meio





Escala: taxonômica, espacial e temporal (?)

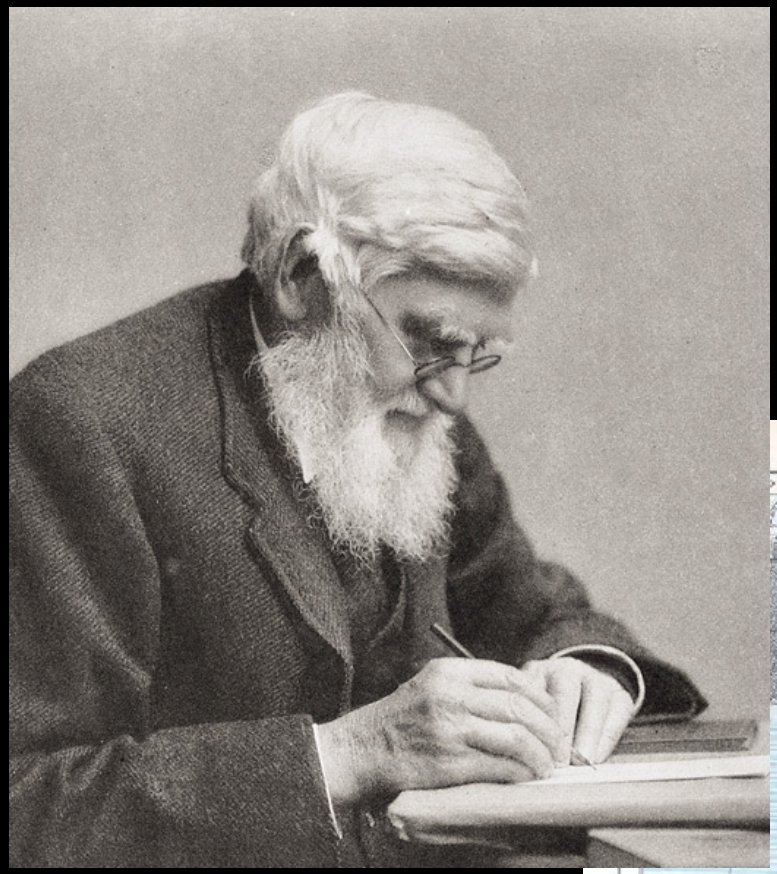
Temas Biogeográficos

- Classificar regiões de acordo com sua biota (flora e fauna): Endemismos

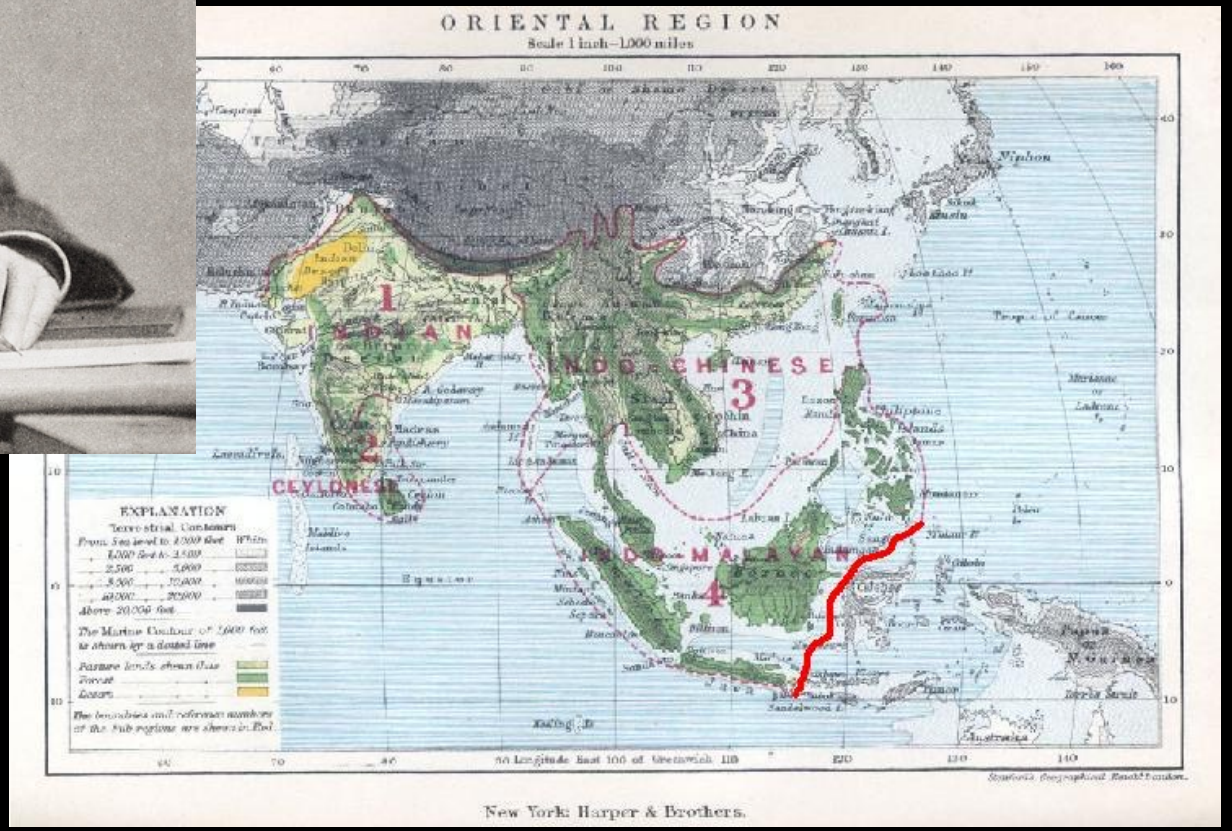
-Reconstruir a história evolutiva de linhagens (origem e diversificação)

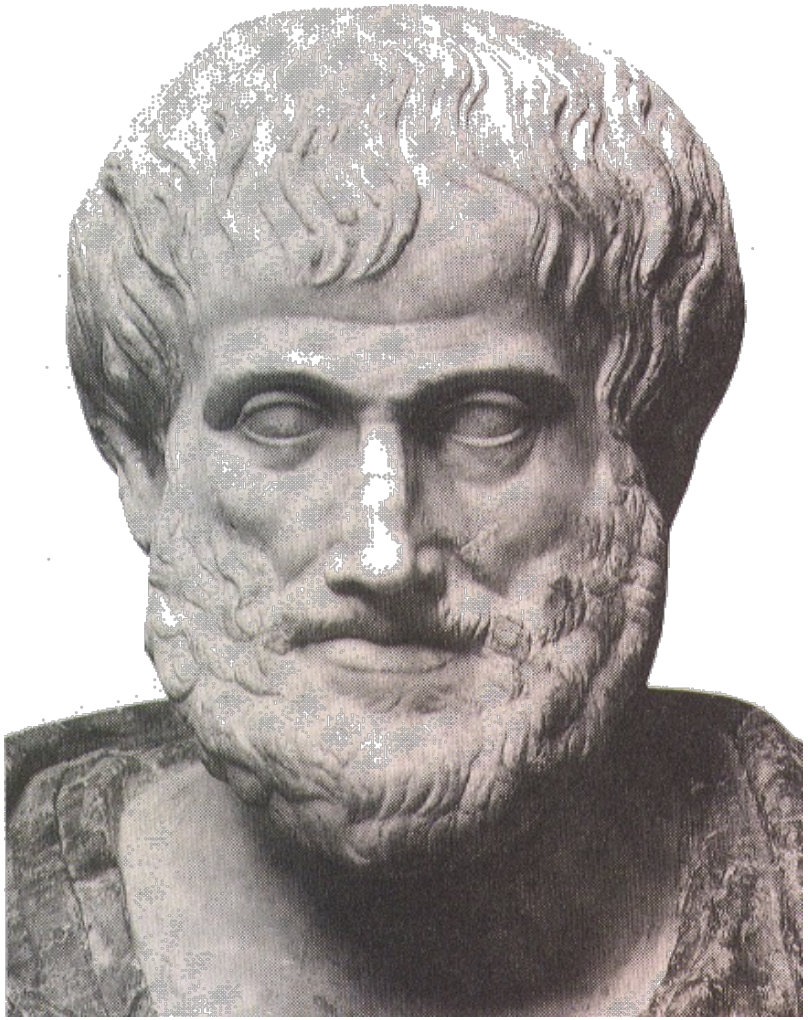
-Explicar diferenças na riqueza e tipos de espécies em área geográficas (latitude, altitude)

- Explicar variação geográfica em populações de espécies próximas (tendências morfológicas)



Histórico


ORIENTAL REGION
Scale 1 inch=1,000 miles
INDIAN
CEYLONESE
INDO-CHINESE
INDO-MALAYAN
EXPLANATION
New York: Harper & Brothers.



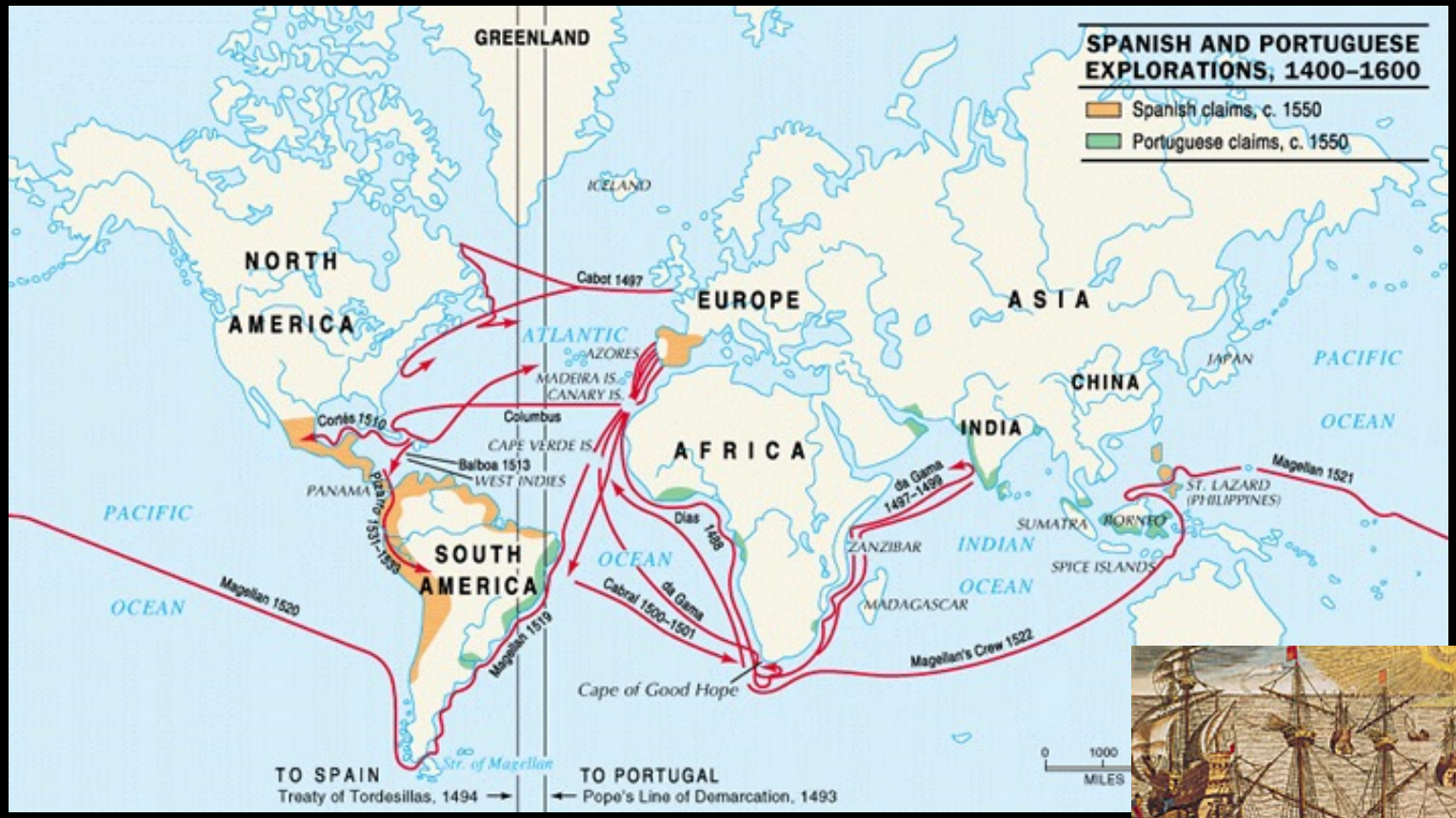
Aristóteles

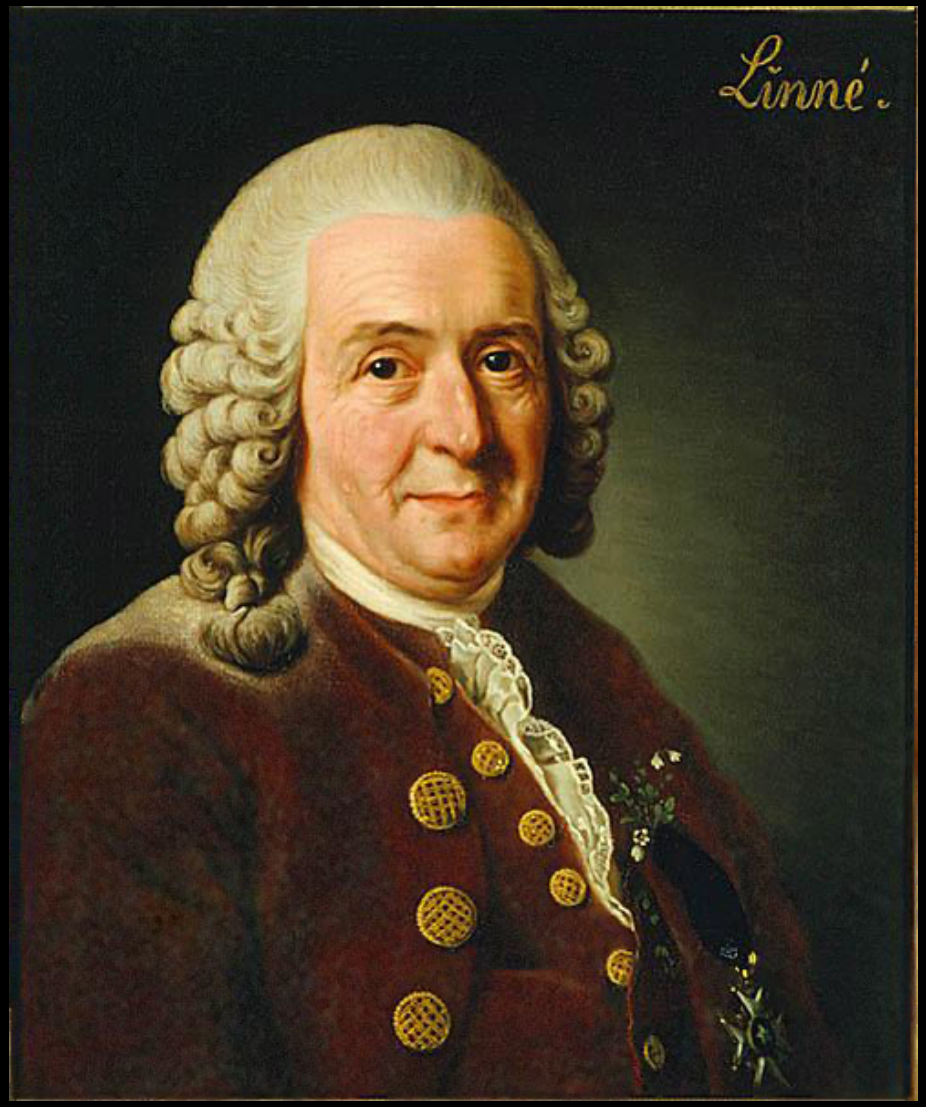
Transgressão e regressão marinha

Escala temporal

355 a.C.

Explorações





Espécies imutáveis
Tipos fixos; *Eidos* Platão

CAROLI LINNAEI
EQVITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. ET BOTAN. PROFESS. VPSAL.
ACAD. VPSAL. HOLMENS. PETROPOL. BEROL. IMPER.
LOND. MONSPEL. TOLOS. FLORENT. SOC.

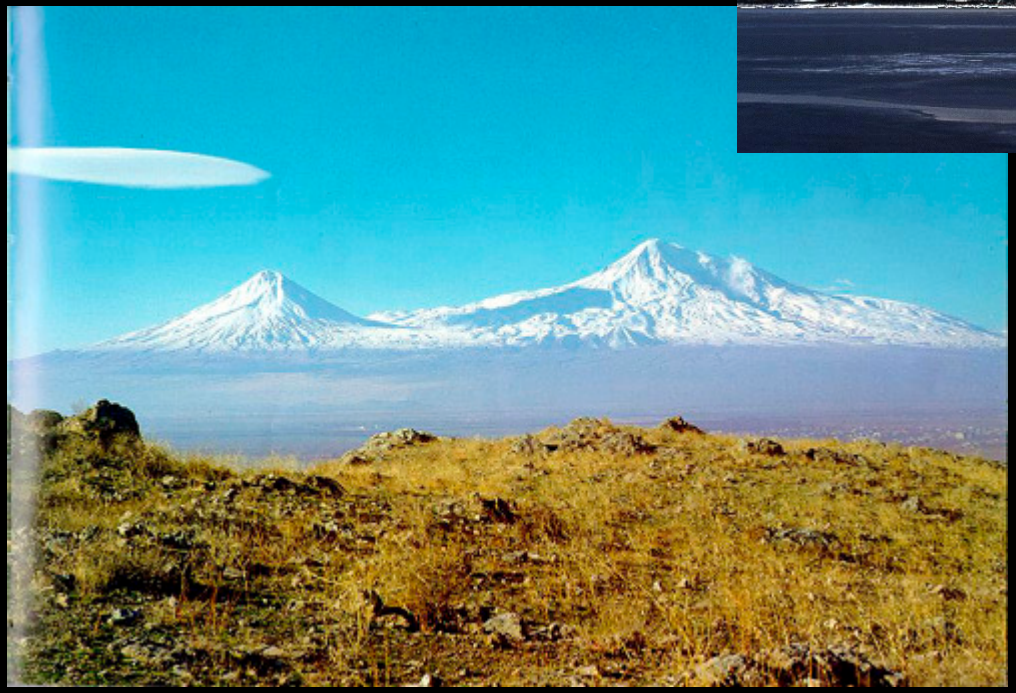
SYSTEMA NATVRAE

PER
REGNA TRIA NATVRAE,
SECVNDVM
CLASSES, ORDINES,
GENERA, SPECIES,
CVM
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.

PRAEFATVS EST
IOANNES IOACHIMVS LANGIVS
MATH. PROF. FVBL. ORD. HALENS. ACAD. IMP. ET BORVSS. COLLEGA.

AD EDITIONEM DECIMAM REFORMATAM HOLMIENSEM.

HALAE MAGDEBVRGICAE
TYPIS ET SVMTIBVS IO. IAC. CVRT. MDCC LX



Musée Buffon à Montbard

HISTOIRE
NATURELLE.

PREMIER DISCOURS.

De la manière d'étudier & de traiter l'Hiſtoire Naturelle.

L'HISTOIRE Naturelle priſe dans toute ſon étendue, eſt une Hiſtoire immenſe, elle embraſſe tous les objets que nous préſente l'Univers. Cette multitude prodigieuſe de Quadrupèdes, d'Oiſeaux, de Poiſſons, d'Inſectes, de Plantes, de Minéraux, &c. offre à la curioſité de l'eſprit humain un vaſte ſpectacle, dont l'enſemble eſt ſi grand, qu'il paroît & qu'il eſt en effet inépuiſable

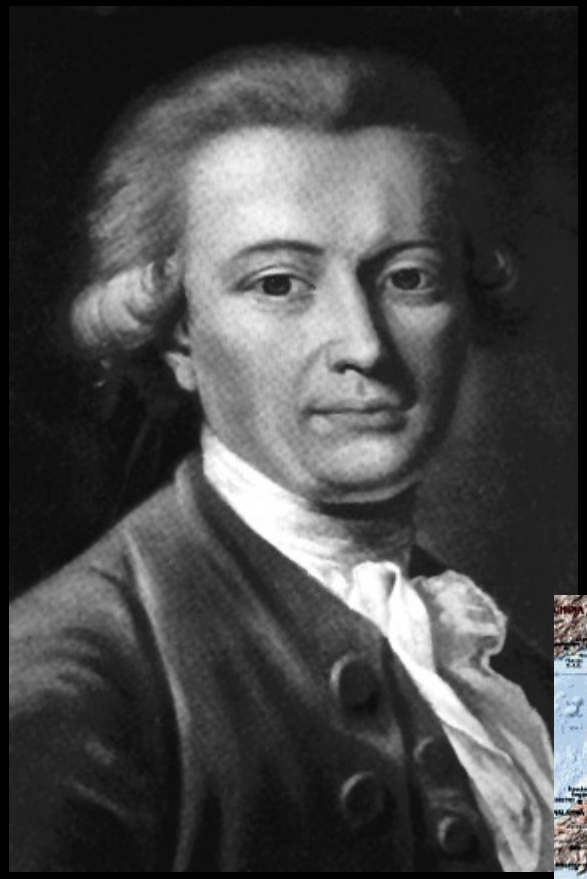
A ij

Lei de Buffon: regiões similares e isoladas, comunidades faunísticas distintas

Terra e espécies dinâmicas

Musée Buffon à Montbard

He brought the idea of evolution into the realm of science. He developed a concept of the "unity of type", a precursor of Comparative Anatomy. More than anyone else, he was responsible for the acceptance of a long-time scale for the history of the earth. He was one of the first to imply that you get inheritance from your parents, in a description based on similarities between elephants and mammoths. And yet, he hindered evolution by his frequent endorsement of the immutability of species. He provided a criterion of species, fertility among members of a species, that was thought impregnable.

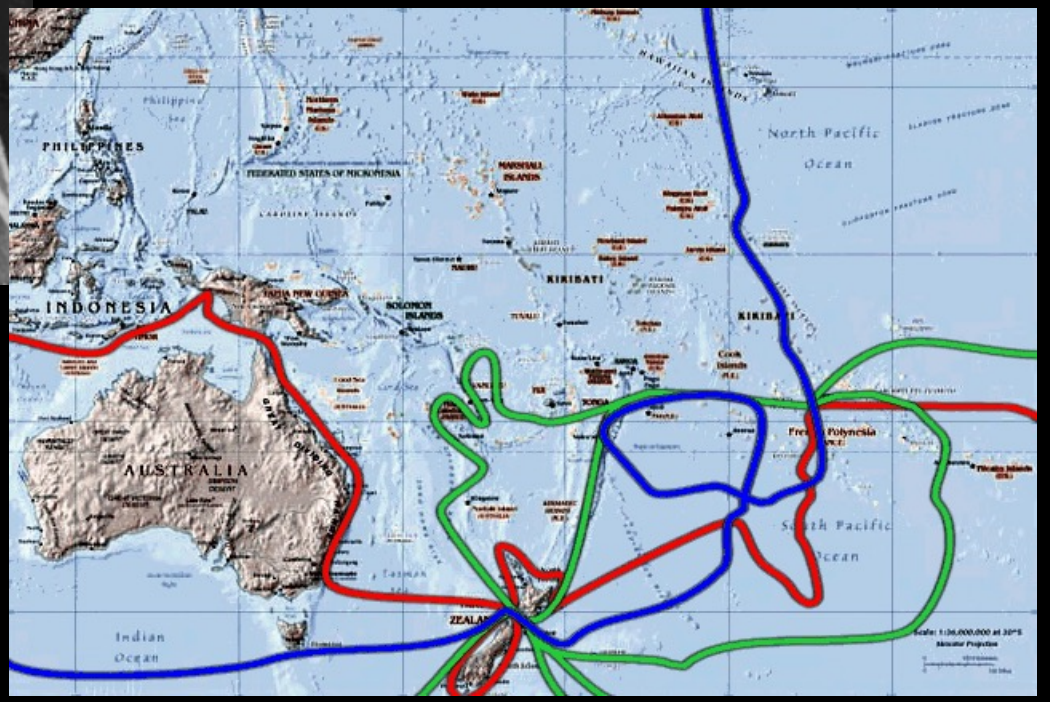


Johann Reinhold Forster

Ilhas: relação tamanho X diversidade

Variação latitudinal

Fitogeografia



RESEARCHES,

Concerning

THE INSTITUTIONS & MONUMENTS

OF

the Ancient Inhabitants

OF

AMERICA,

with Descriptions & Views

OF SOME OF THE MOST

Striking Scenes

in the

CORDILLERAS!

Written in French by

ALEXANDER DE HUMBOLDT,

& Translated into English by

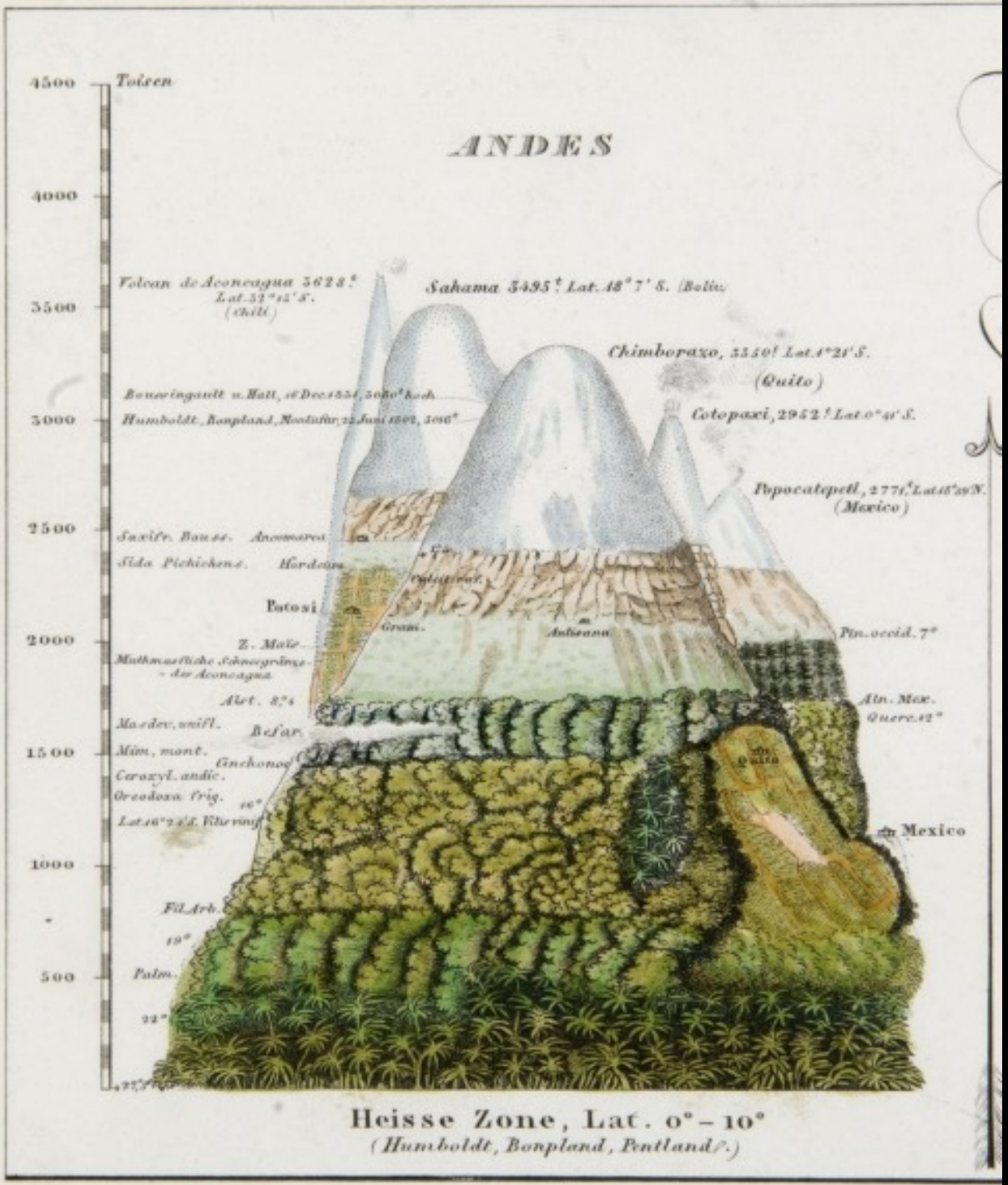
Helen Maria Williams.

Vol. I.

VIEW OF COTOPAXI.

LONDON:

Published by Longman, Hurst, Rees, Orme & Brown, J. Murray & H. Colburn.


ANDES
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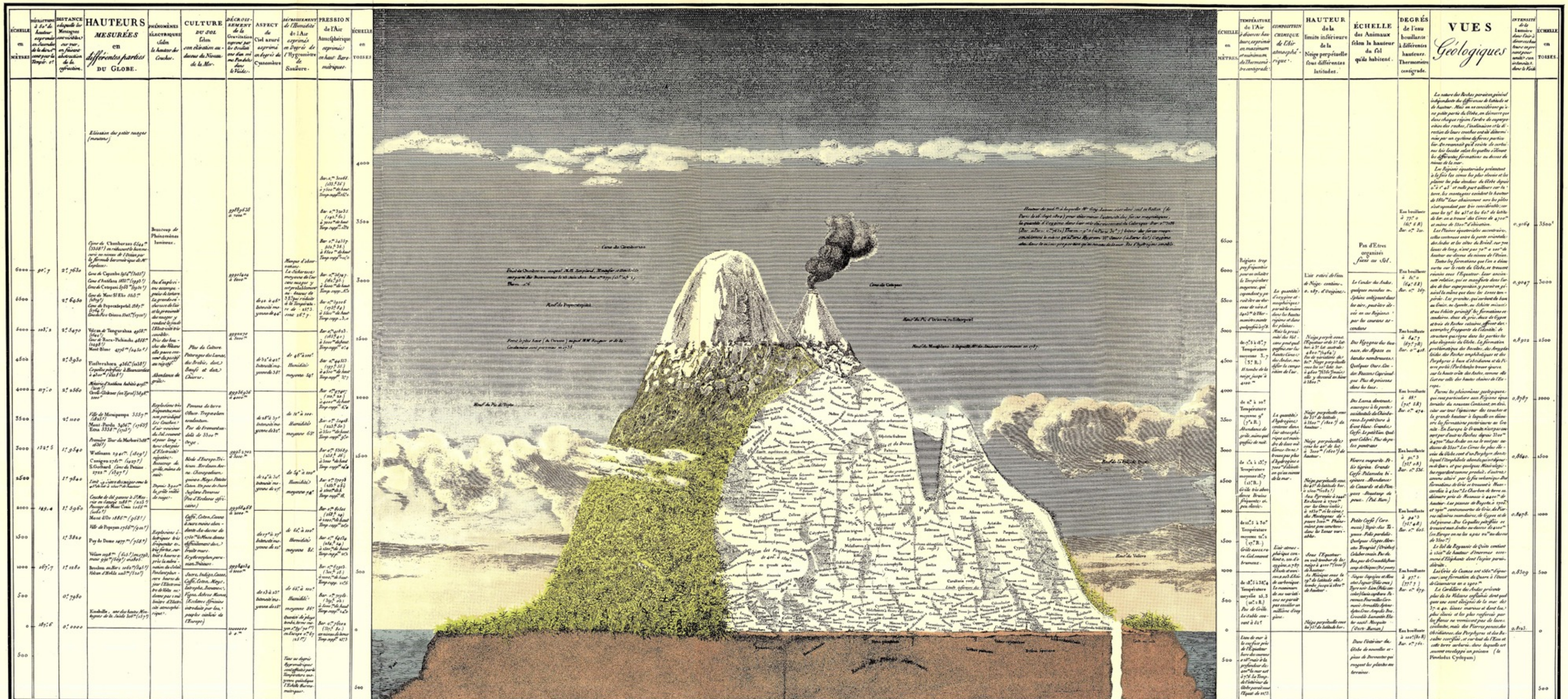
Toisen
4000
3500
3000
2500
2000
1500
1000
500
Volcan de Aconcagua 3628.t
Lat. 32°42' S.
(Chili)
Sahama 3495 t Lat. 18° 7' S. (Bolivia)
Chimborazo, 3350 t Lat. 1°21' S.
(Quito)
Cotopaxi, 2942 t Lat. 0°46' S.
Popocatepetl, 2771 t Lat. 18°29 N.
(Mexico)
Bonpland, Montalvo, 22 Juni 1801, 3016
Saxifr. Bauer. Ancomarca
Sida Pichichensis. Hordeum
Potosi
Z. Mais
Art. 8,4
Mim. mant.
Ginchona
Ceroxyl. andic.
Oreodoxa frig.
Lat. 18°24' S.
Fil. Arb.
Palm.
Granat.
Antisana
Pin. occid. 7°
Aln. Mex.
Quercus 12°
Mexico
Heisse Zone, Lat. 0° – 10°
(Humboldt, Bonpland, Pentland &c.)



GÉOGRAPHIE DES PLANTES ÉQUINOXIALES.

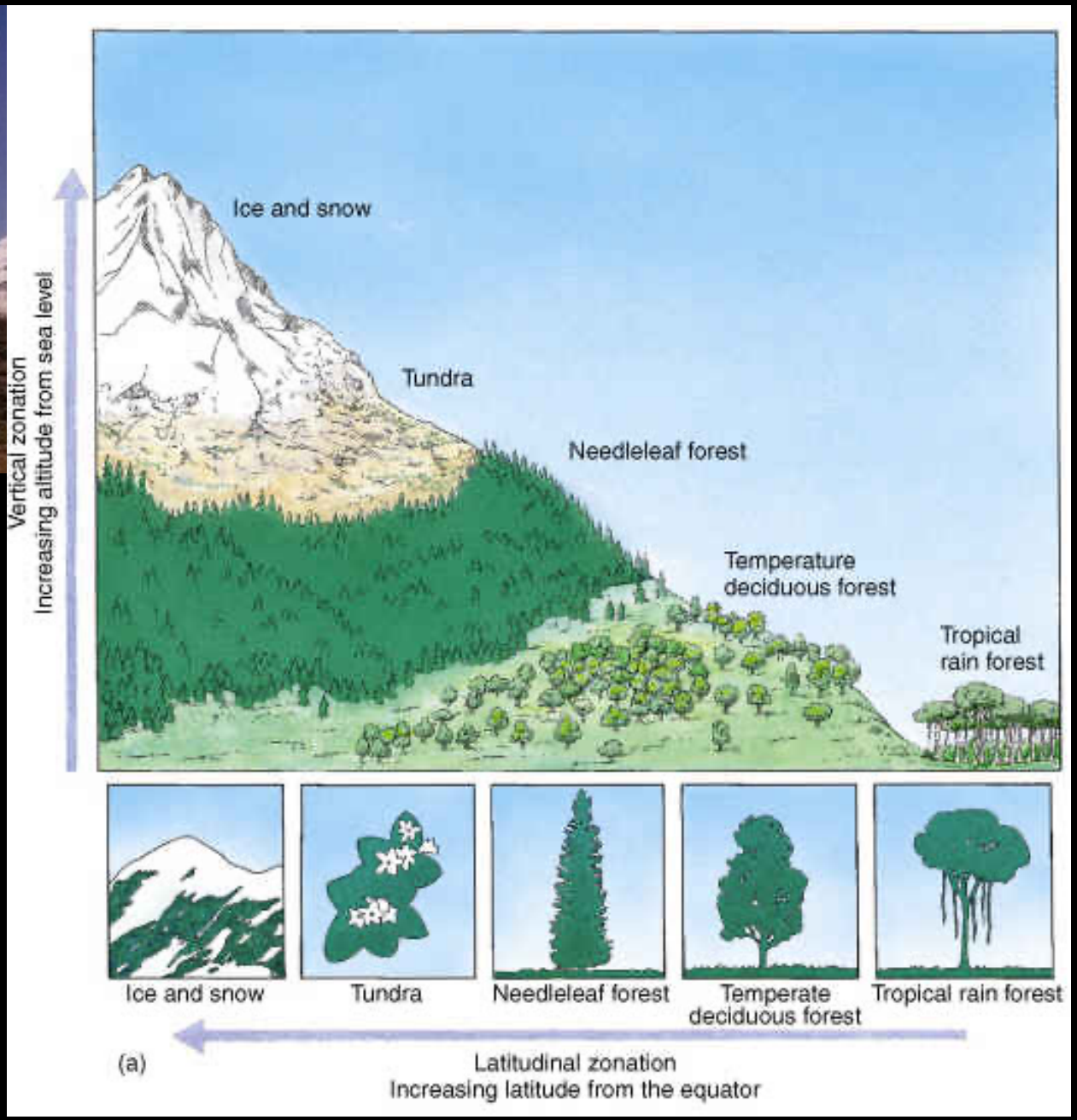
Tableau physique des Andes et Pays voisins

Dressé d'après des Observations & des Mesures prises Sur les Lieux depuis le 10.e degré de latitude boréale jusqu'au 10.e de latitude australe en 1799, 1800, 1801, 1802 et 1803.

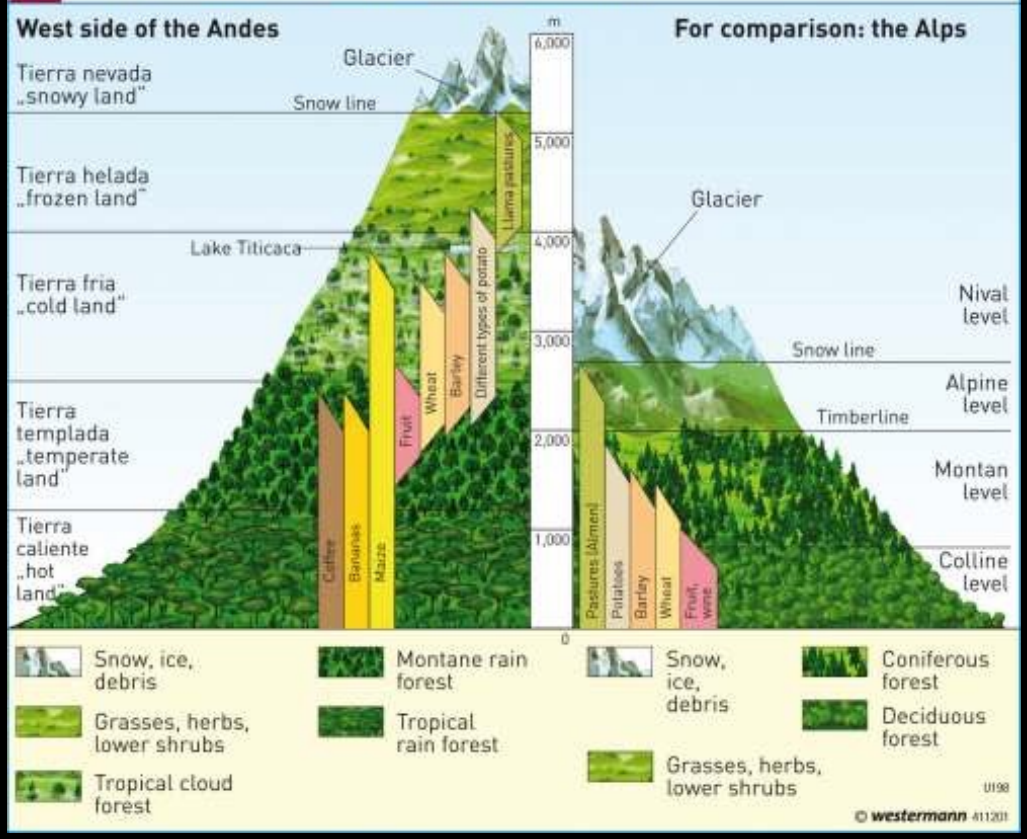
PAR

ALEXANDRE DE HUMBOLDT ET AIMÉ BONPLAND.

Esquissé et rédigé par M. de Humboldt, dessiné par Schönberger et Turpin à Paris en 1805, gravé par Bouquet, la Lettre par Beaublé, imprimé par Langlois.


Ice and snow
Tundra
Needleleaf forest
Temperature deciduous forest
Tropical rain forest
Vertical zonation
Increasing altitude from sea level
Ice and snow
Tundra
Needleleaf forest
Temperate deciduous forest
Tropical rain forest
(a)
Latitudinal zonation
Increasing latitude from the equator

2 The Andes – Altitudinal zonation



Isolíneas: pressão atmosférica e temperatura

Zonação latitudinal = altitudinal

Cinturões florísticos

Comunidades x Clima

Mais de um sítio de Criação (montanhas)
Willdenow

Alphonse de Candolle

Clima: condições abióticas (temp., pluv.)

Competição por recursos e luta pela sobrevivência

Século XIX

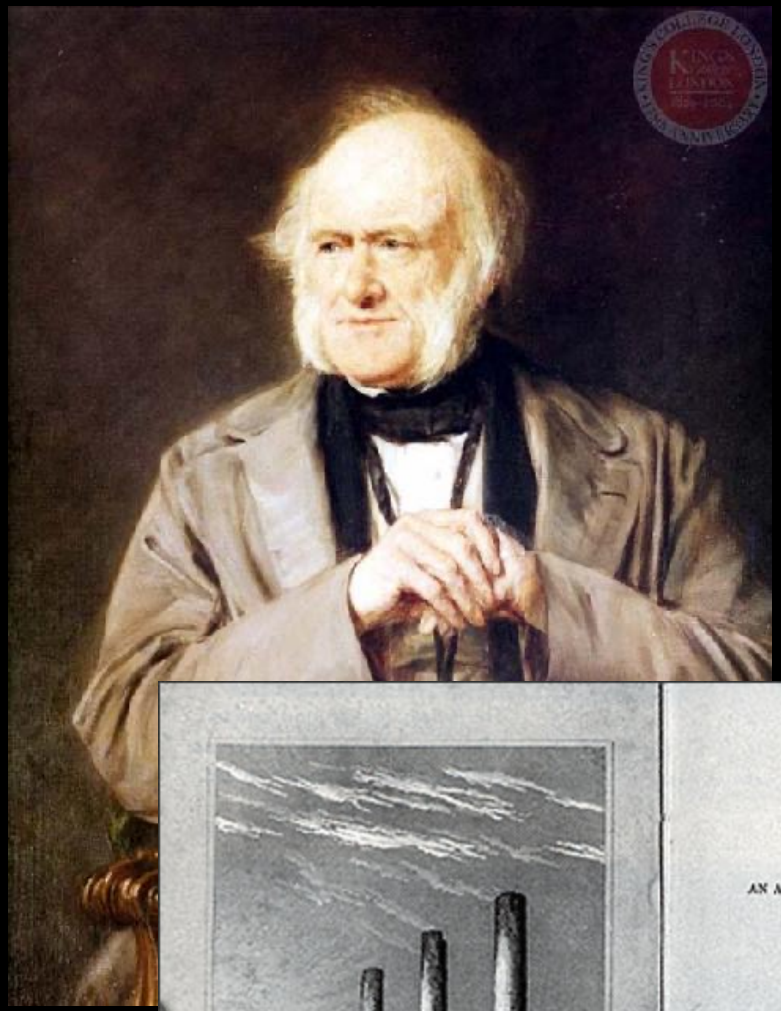
Mundo estático e imutável

↓

Mundo dinâmico

> Área, > Riqueza

Equador > riqueza



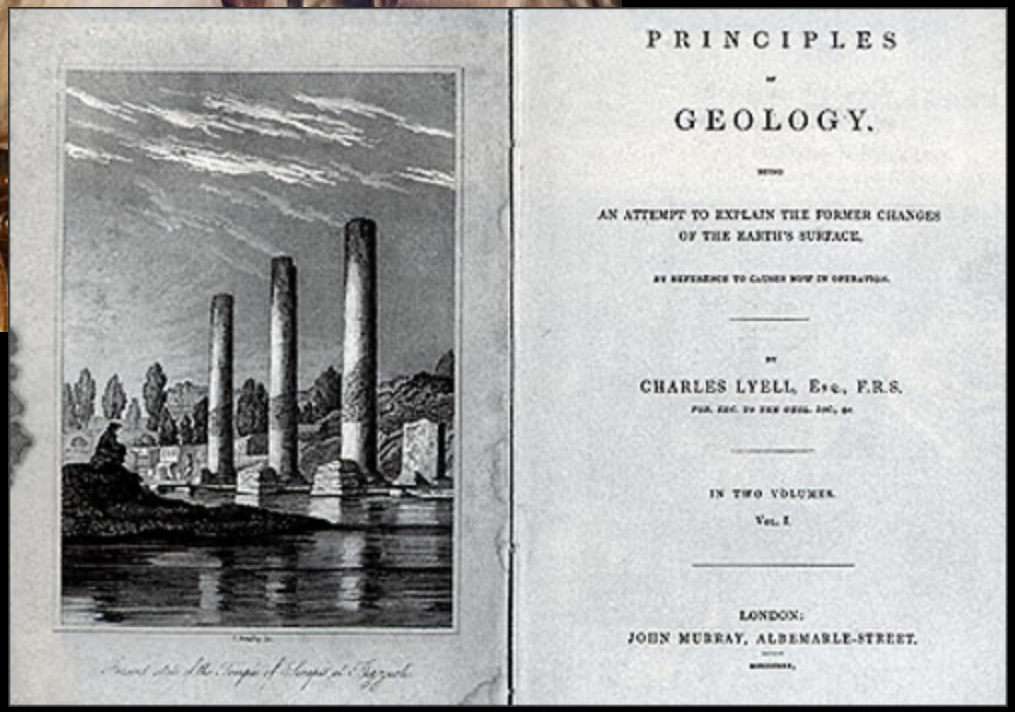
Terra dinâmica: variação climática

Extinção

Vários sítios de Criação ao longo do tempo

Idade geológica da Terra: mais antiga

Uniformitarismo



PRINCIPLES

OF

GEOLOGY,

BEING

AN ATTEMPT TO EXPLAIN THE FORMER CHANGES OF THE EARTH'S SURFACE,

BY REFERENCE TO CAUSES NOW IN OPERATION.

BY

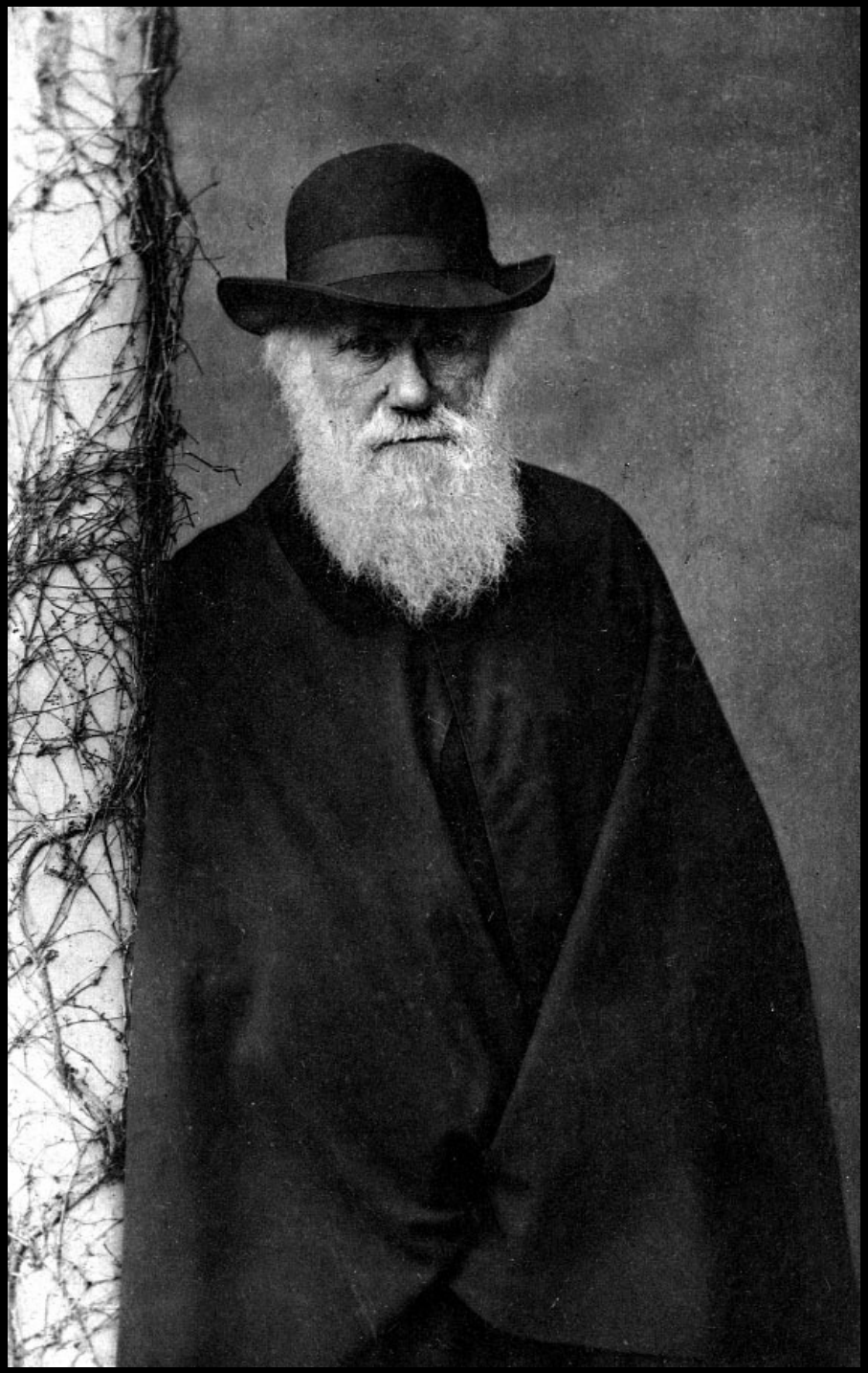
CHARLES LYELL, Esq., F.R.S.

IN TWO VOLUMES.

Vol. I.

LONDON:

JOHN MURRAY, ALBEMARLE-STREET.



ON

THE ORIGIN OF SPECIES

BY MEANS OF NATURAL SELECTION,

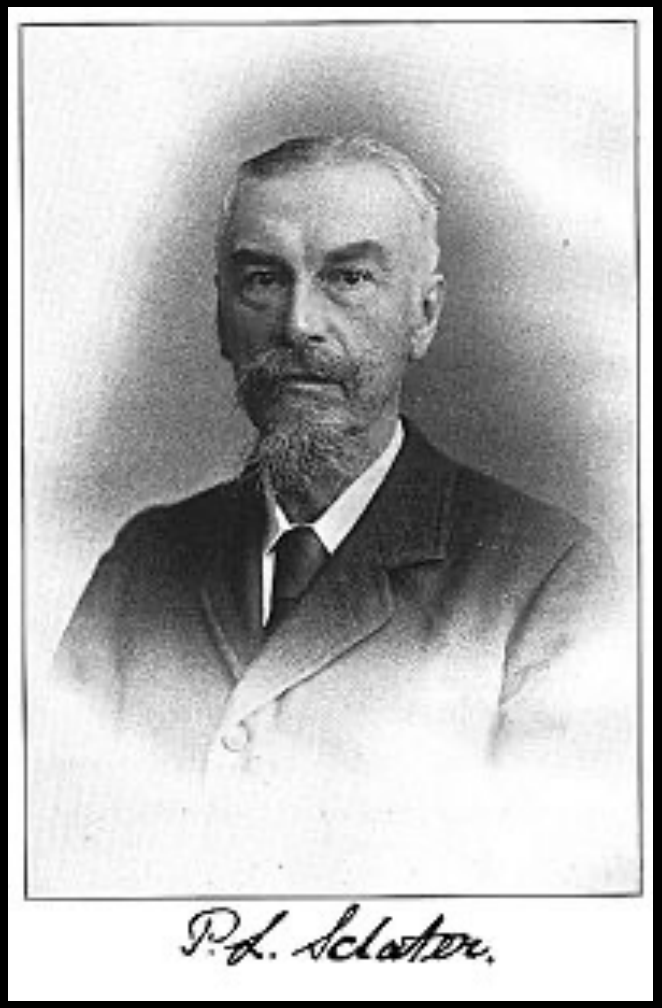
OR THE

PRESERVATION OF FAVOURED RACES IN THE STRUGGLE FOR LIFE.

By CHARLES DARWIN, M.A.,

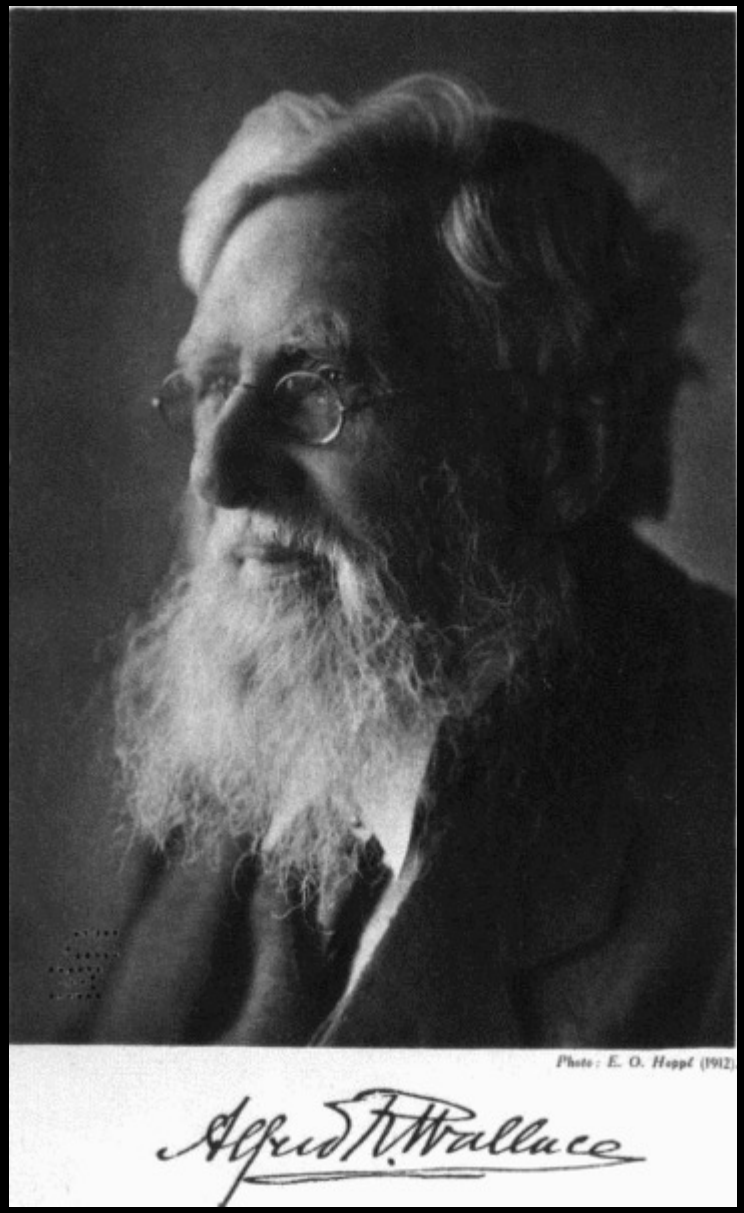
FELLOW OF THE ROYAL, GEOLOGICAL, LINNÆAN, ETC., SOCIETIES;
AUTHOR OF 'JOURNAL OF RESEARCHES DURING H. M. S. BEAGLE'S VOYAGE ROUND THE WORLD.'

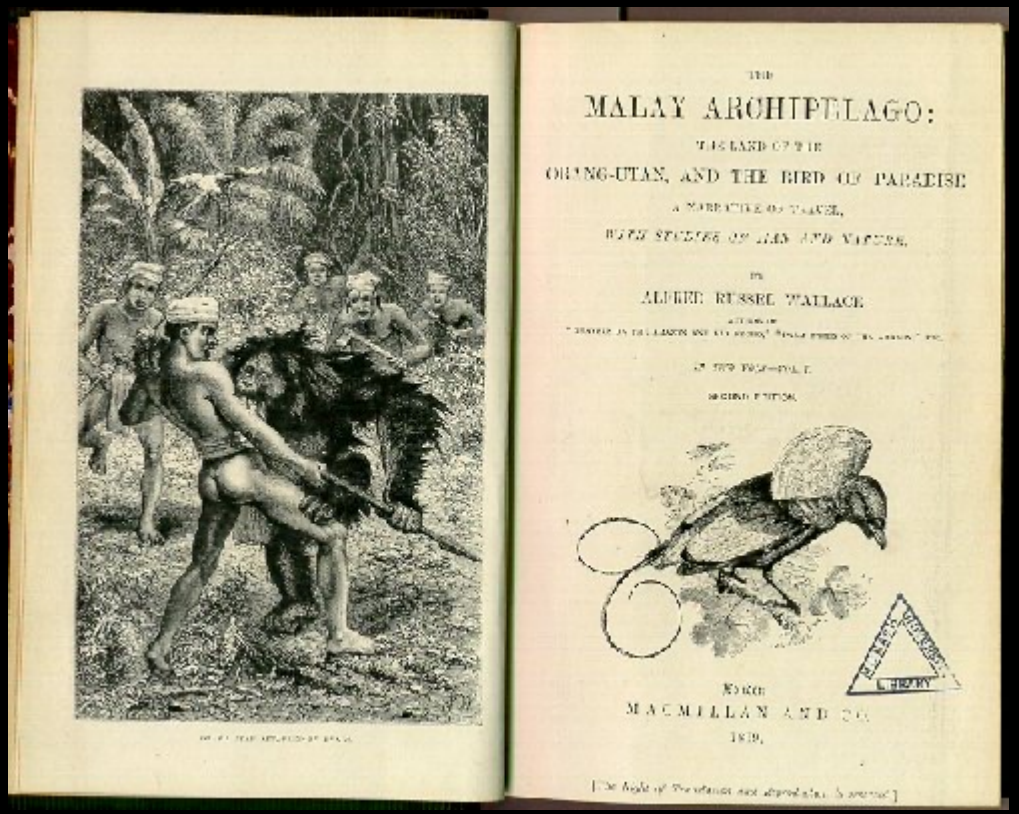
LONDON:
JOHN MURRAY, ALBEMARLE STREET.
1859.

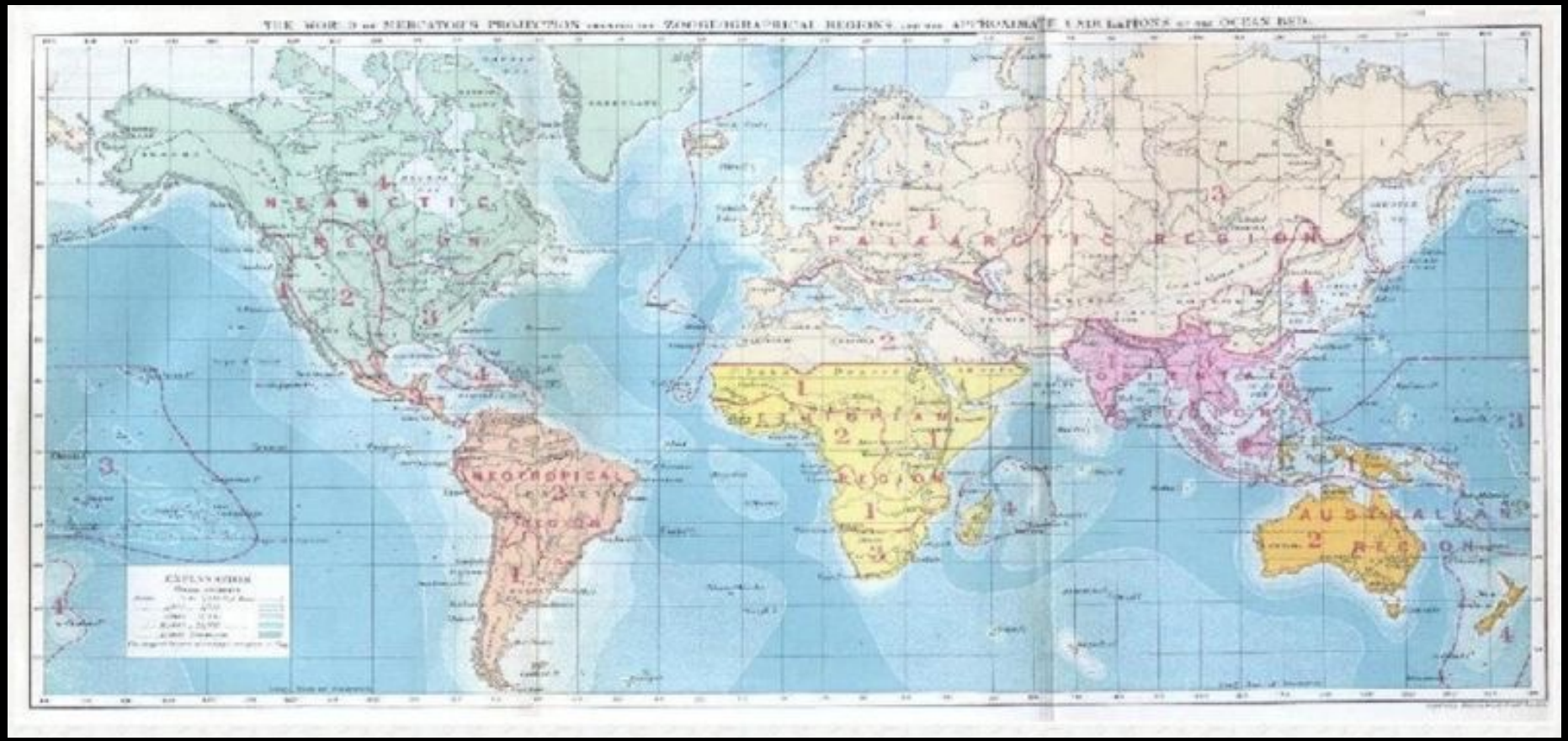


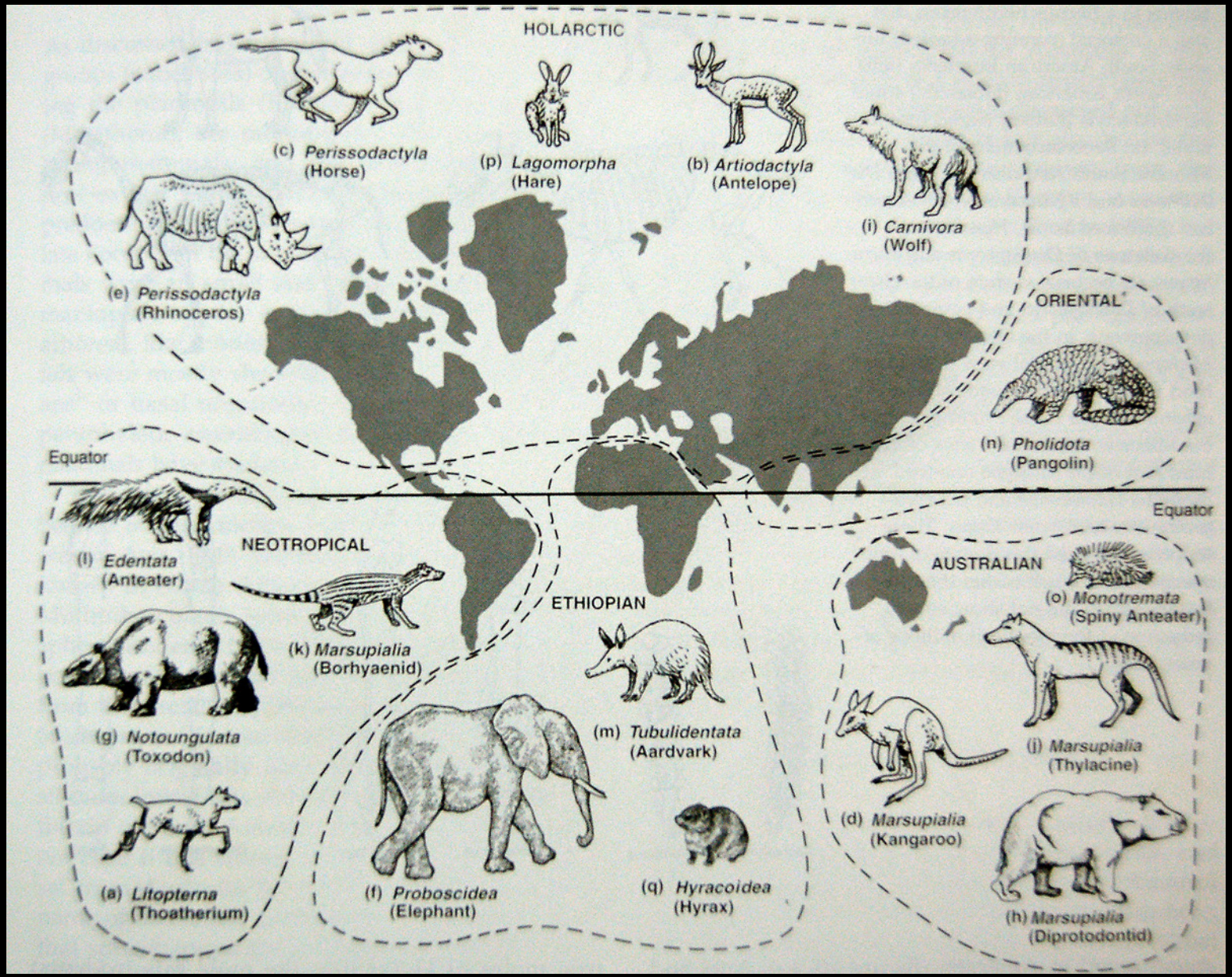
"...the most natural primary ontological divisions of the Earth's surface..."

Regiões Zoogeográficas



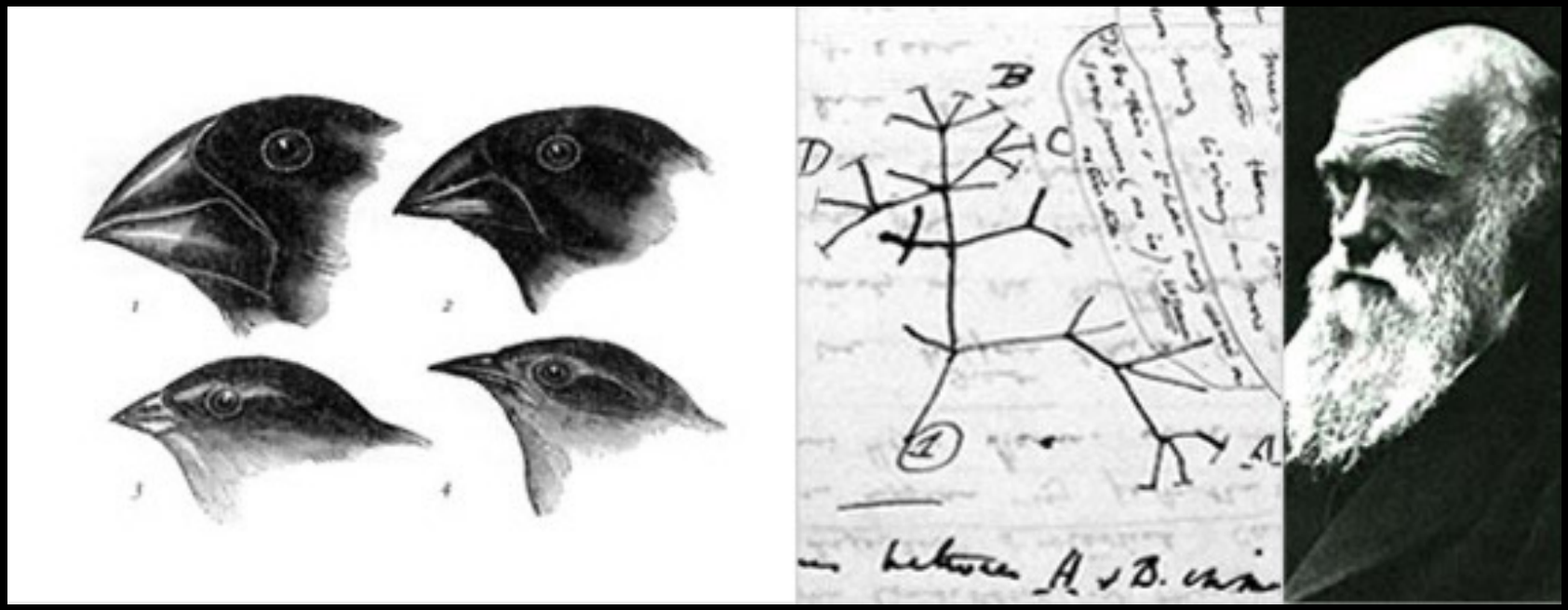



NEARCTIC
REGION
PALAEARCTIC REGION
ETHIOPIAN
REGION
NEOTROPICAL
REGION
AUSTRALIAN
REGION
EXPLANATION


HOLARCTIC
(c) Perissodactyla (Horse)
(p) Lagomorpha (Hare)
(b) Artiodactyla (Antelope)
(i) Carnivora (Wolf)
(e) Perissodactyla (Rhinoceros)
ORIENTAL
(n) Pholidota (Pangolin)
Equator
Equator
(l) Edentata (Anteater)
NEOTROPICAL
(k) Marsupialia (Borhyaenid)
ETHIOPIAN
AUSTRALIAN
(o) Monotremata (Spiny Anteater)
(g) Notoungulata (Toxodon)
(m) Tubulidentata (Aardvark)
(j) Marsupialia (Thylacine)
(d) Marsupialia (Kangaroo)
(a) Litopterna (Thoatherium)
(f) Proboscidea (Elephant)
(q) Hyracoidea (Hyrax)
(h) Marsupialia (Diprotodontid)

Biogeografia

Presente e passado



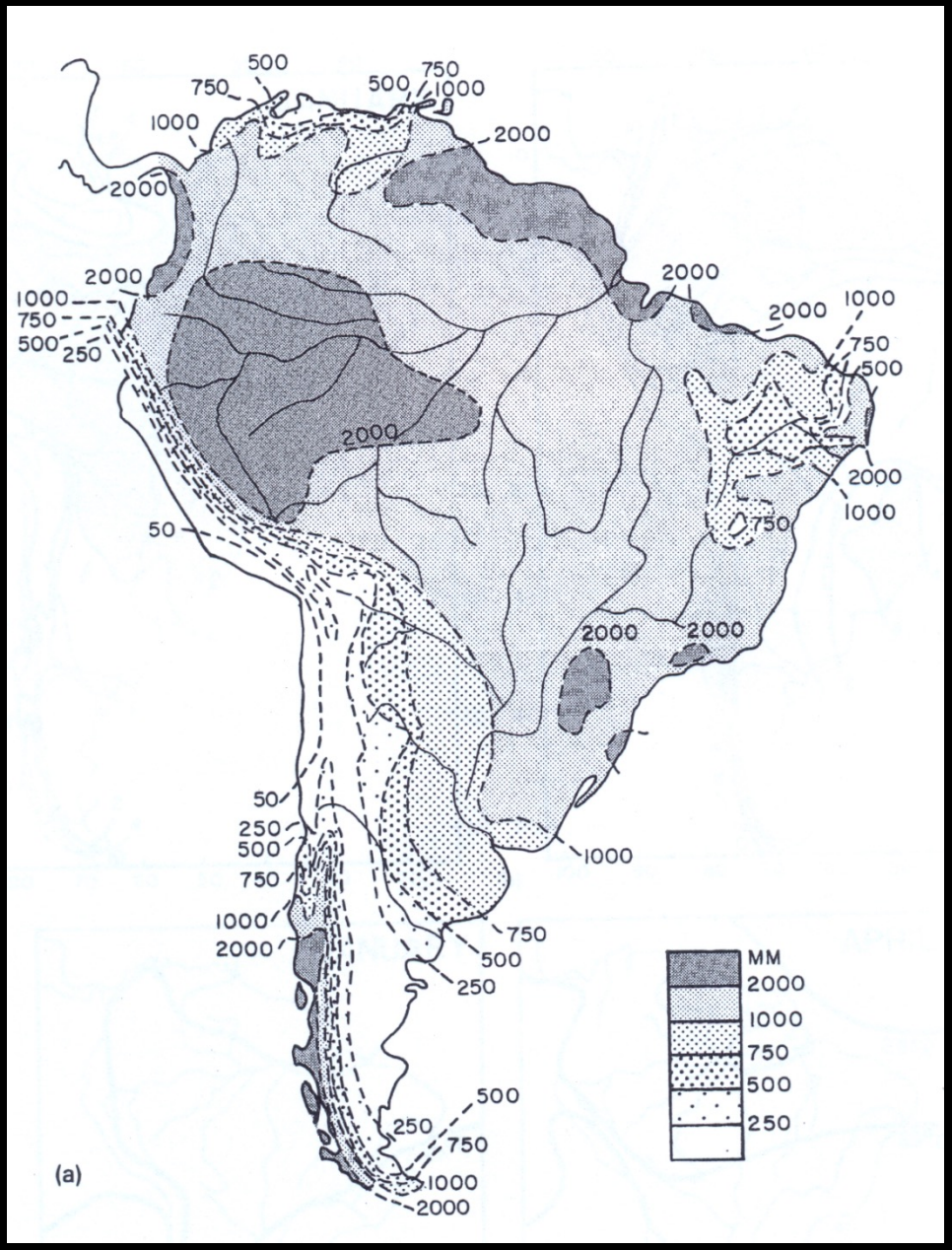
Espécies X Geografia

Condições abióticas: clima, geografia

Condições bióticas: florística, fitofisionomias

Atuais e Pretéritas


Magdalena
Maracaibo
Atrato
Orinoco
Essequibo
●=Casiquiare
San Juan
Amazon
São
Francisco
Titicaca
Paraíba
do Sul
Paraná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MM
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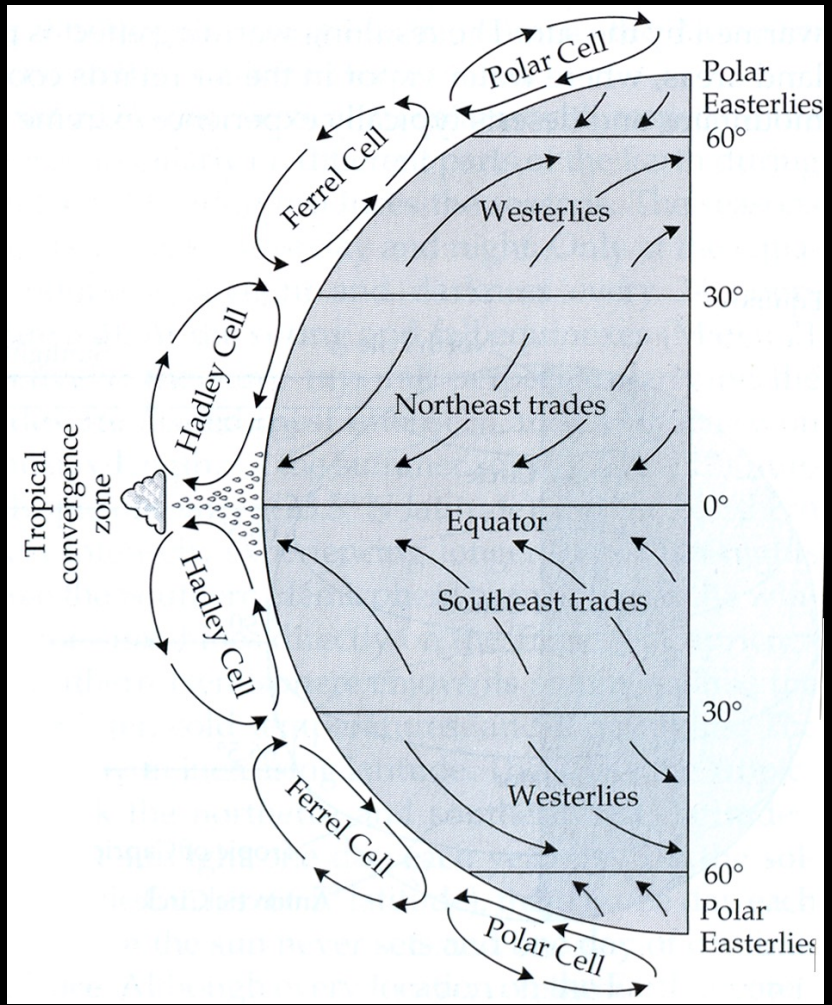
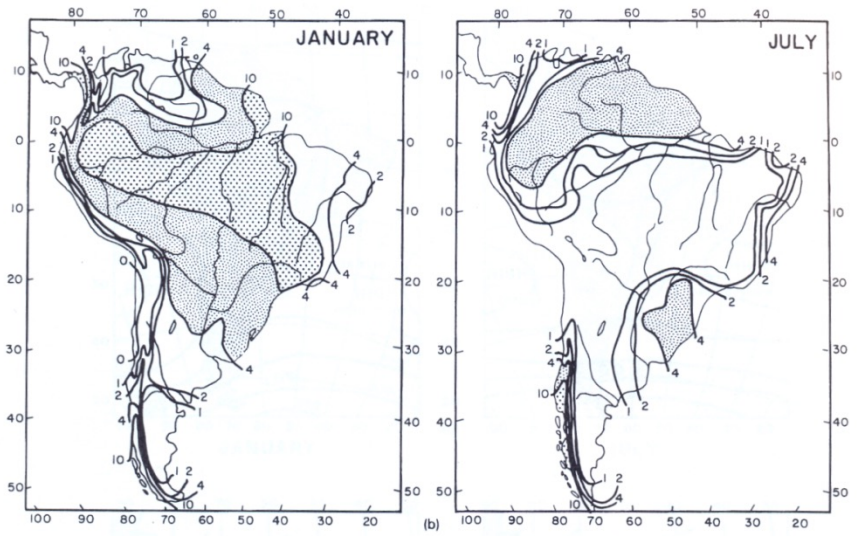
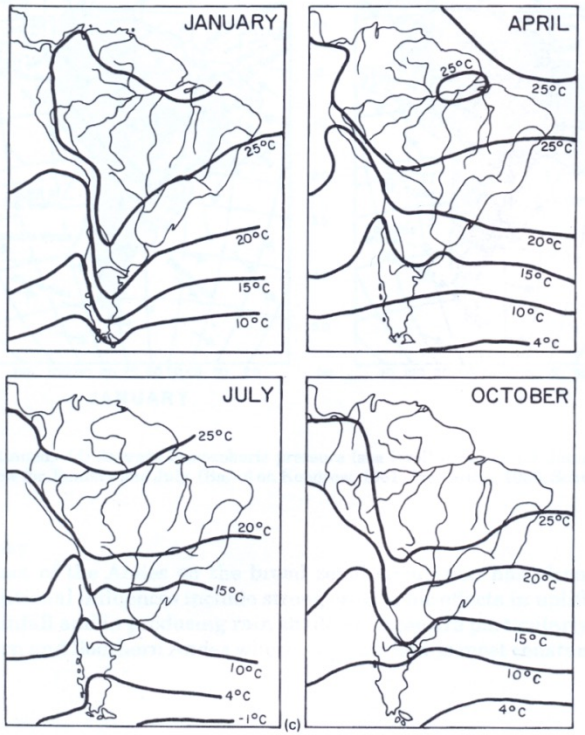
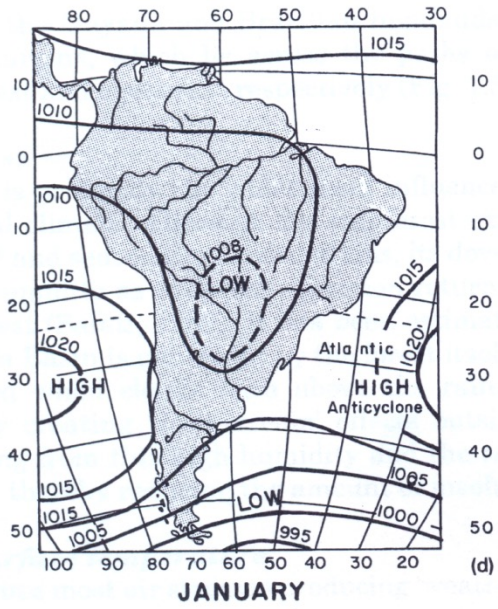
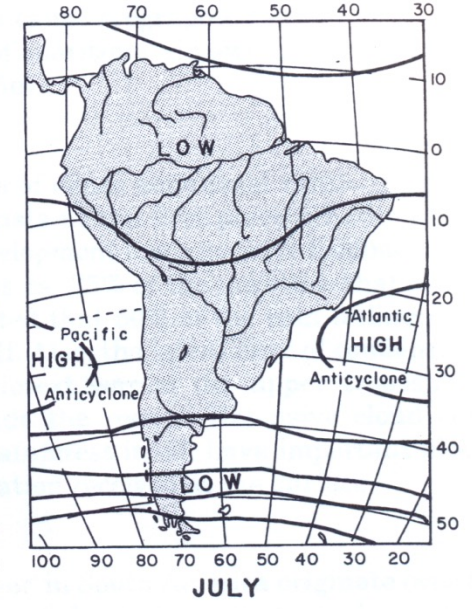
750
500
250
(a)


Polar Cell
Polar Easterlies
60°
Ferrel Cell
Westerlies
30°
Hadley Cell
Northeast trades
Tropical convergence zone
0°
Equator
Hadley Cell
Southeast trades
30°
Ferrel Cell
Westerlies
60°
Polar Easterlies
Polar Cell

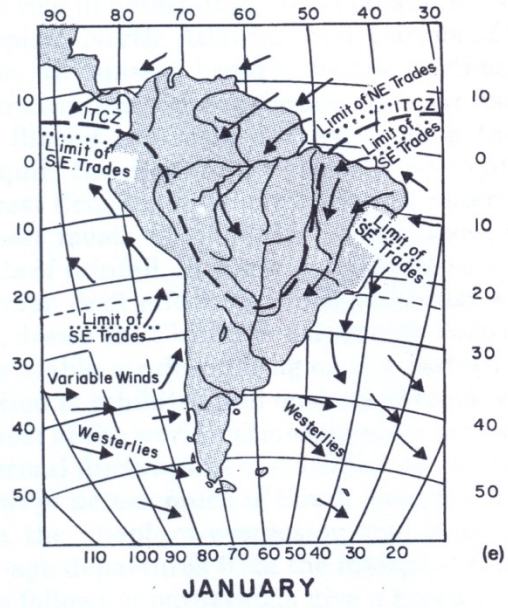

JANUARY
JULY
(b)

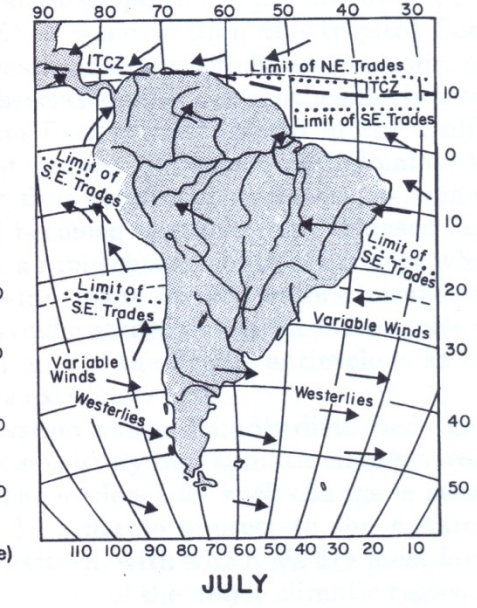

JANUARY
APRIL
JULY
OCTOBER
25°C
20°C
15°C
10°C
4°C
-1°C
(c)


1015
1010
1008
LOW
HIGH
Atlantic
Anticyclone
1020
1005
995
1000
1085
JANUARY

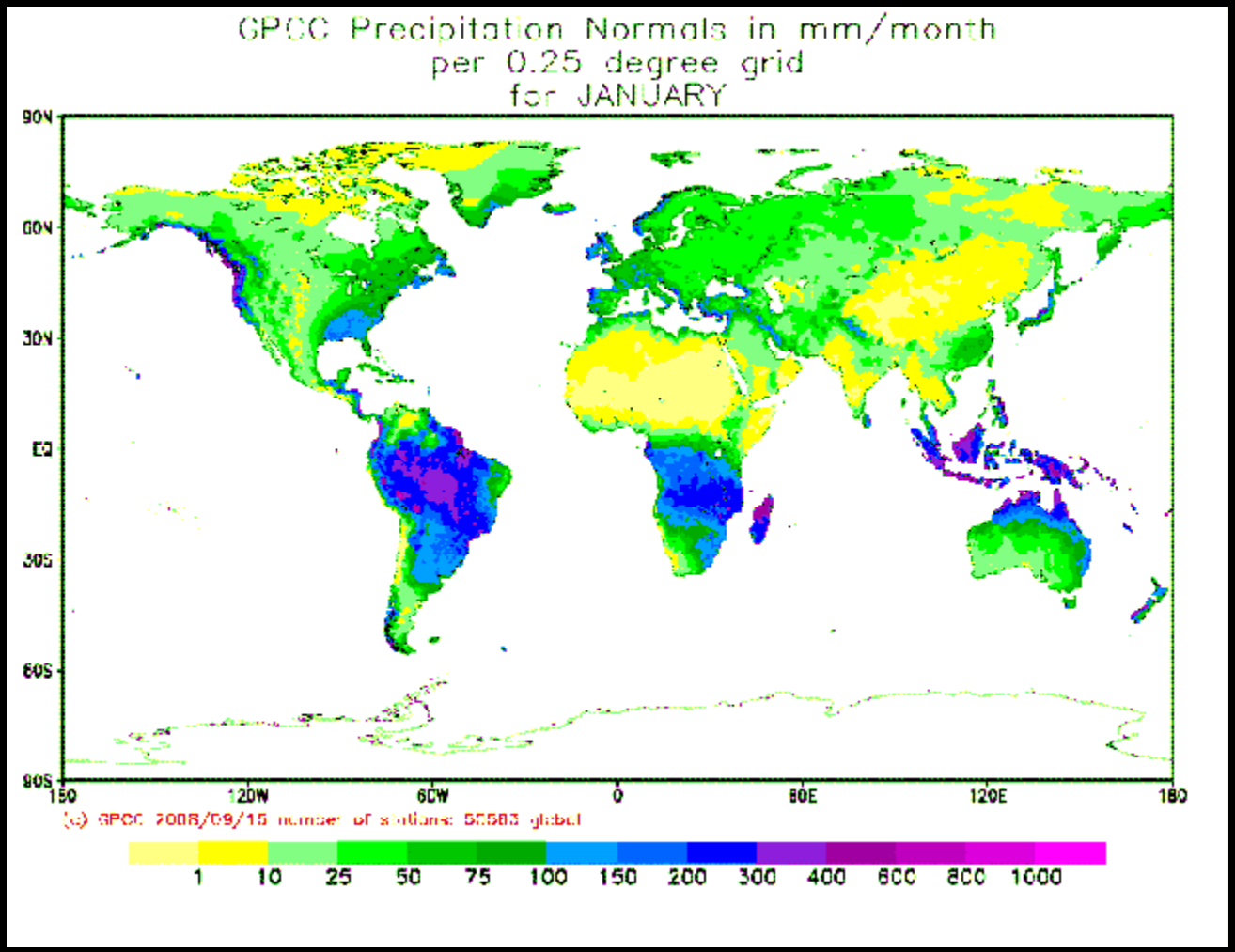

LOW
Pacific
HIGH
Anticyclone
Atlantic
HIGH
Anticyclone
LOW
JULY

(d)

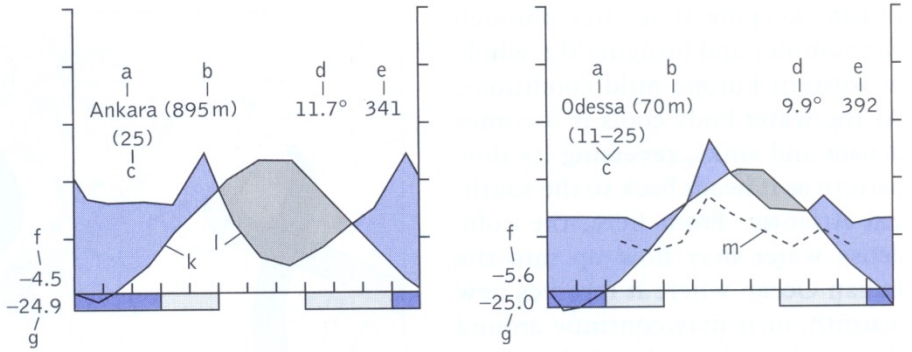

ITCZ
Limit of NE. Trades
Limit of SE. Trades
Variable Winds
Westerlies
JANUARY


ITCZ
Limit of N.E. Trades
Limit of SE. Trades
Variable Winds
Westerlies
JULY

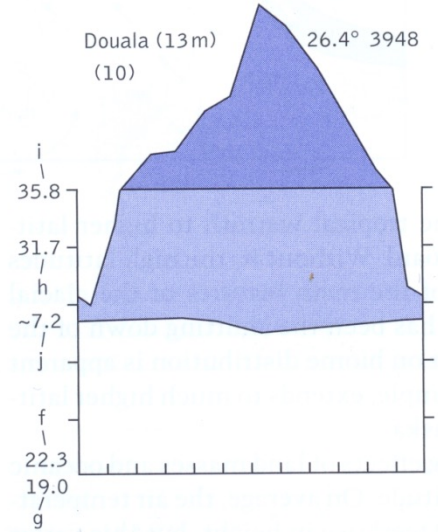
(e)

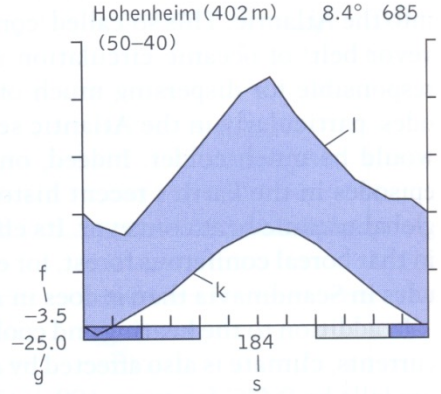

GPCC Precipitation Normals in mm/month
per 0.25 degree grid
for JANUARY
90N
60N
30N
EQ
30S
60S
90S
150
120W
60W
0
60E
120E
180
(c) GPCC 2008/09/15 number of stations: 55583 global
1
10
25
50
75
100
150
200
300
400
600
800
1000

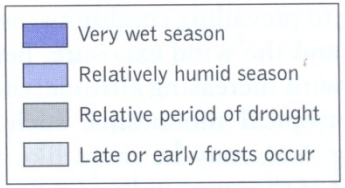

80°
70°
60°
50°
40°
10°
0°
Orinoco
Equator
Amazon
CORDILLERA DE LOS ANDES
Tropic of Capricorn
Parana
20°
30°
40°
50°
REGIONAL CLIMATIC ZONES
West of Andes
Equatorial
Sub-Tropical Dry
Warm Temperate
Cool Temperate
East of Andes
Cool-Warm Temperate
Sub-Tropical
Tropical
Equatorial
0
1000km
80°
60°
50°
40°
30°

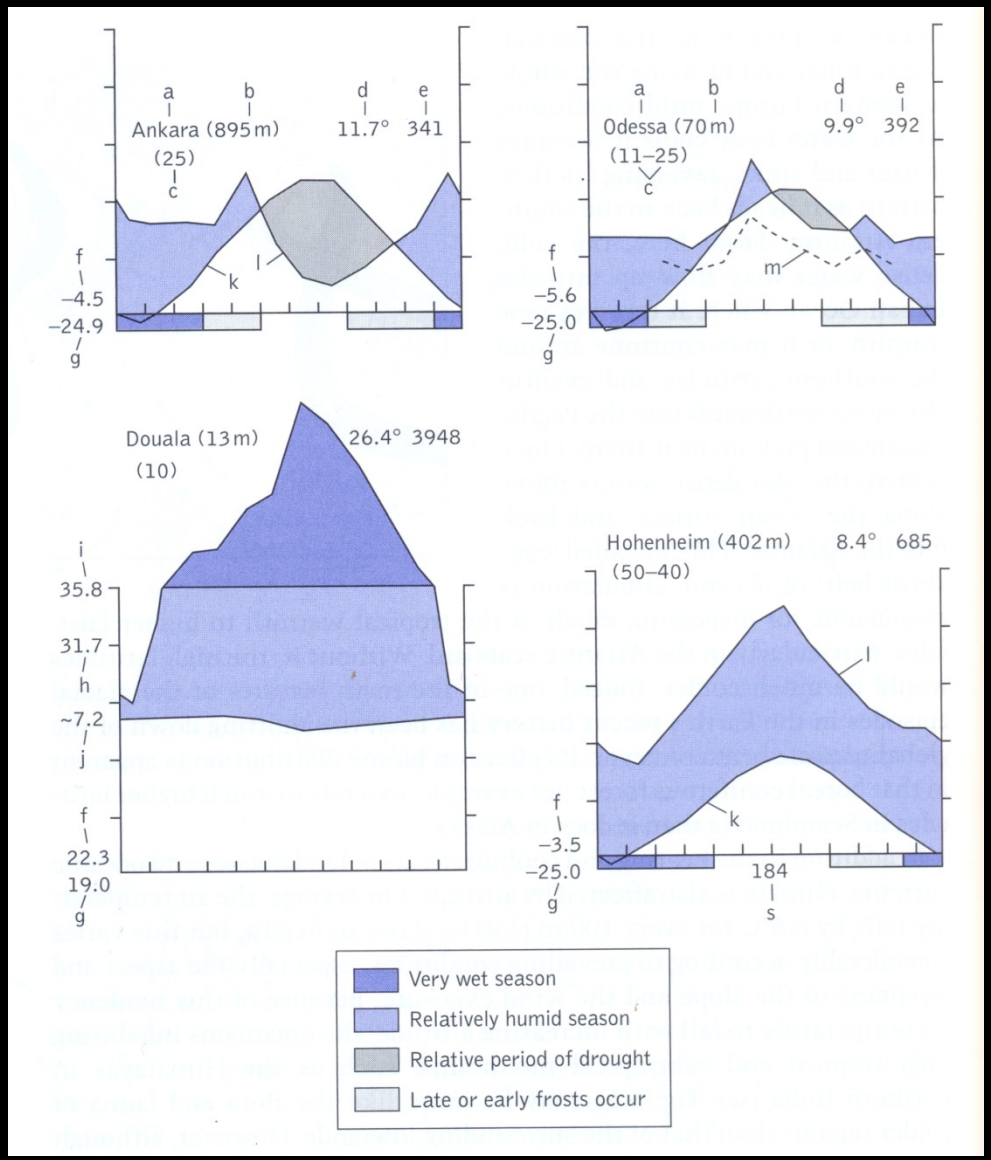

a
b
d
e
Ankara (895 m)
11.7° 341
(25)
c
f
−4.5
−24.9
g
k
l

a
b
d
e
Odessa (70 m)
9.9° 392
(11–25)
c
f
−5.6
−25.0
g
m


Douala (13 m)
26.4° 3948
(10)
i
35.8
31.7
h
~7.2
j
f
22.3
19.0
g


Hohenheim (402 m)
8.4° 685
(50–40)
l
k
f
−3.5
−25.0
g
184
s


Very wet season
Relatively humid season
Relative period of drought
Late or early frosts occur



a. Estação

b. Altitude a.n.m.

c. Tempo de observação

d. Temp. média anual

e. Precipitação média anual

f. Temp. média mínima diária

g. Temp. mais baixa registrada

h. Temp. média máxima diária

i. Temp. mais alta registrada

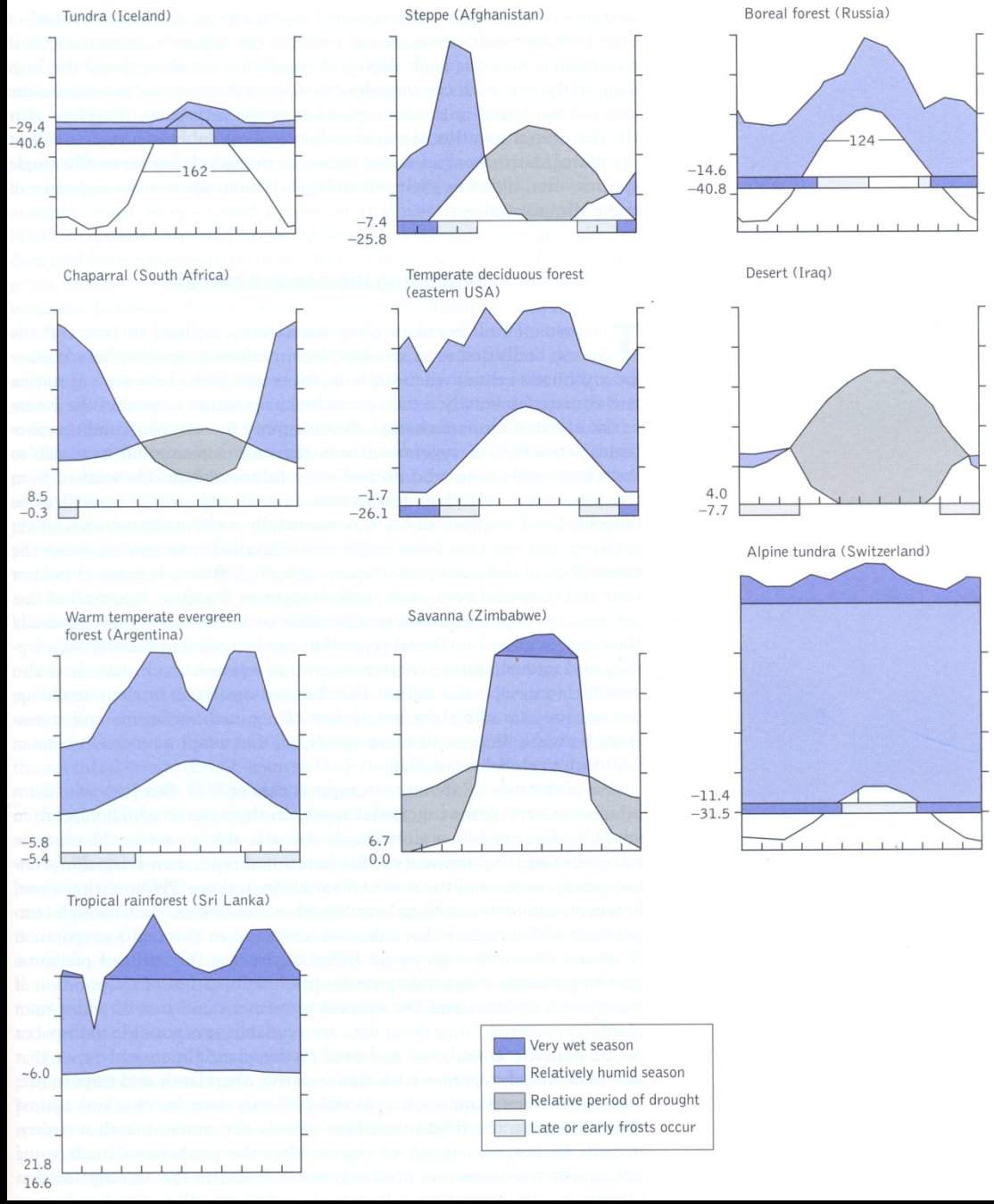
j. Variação média diária de t.

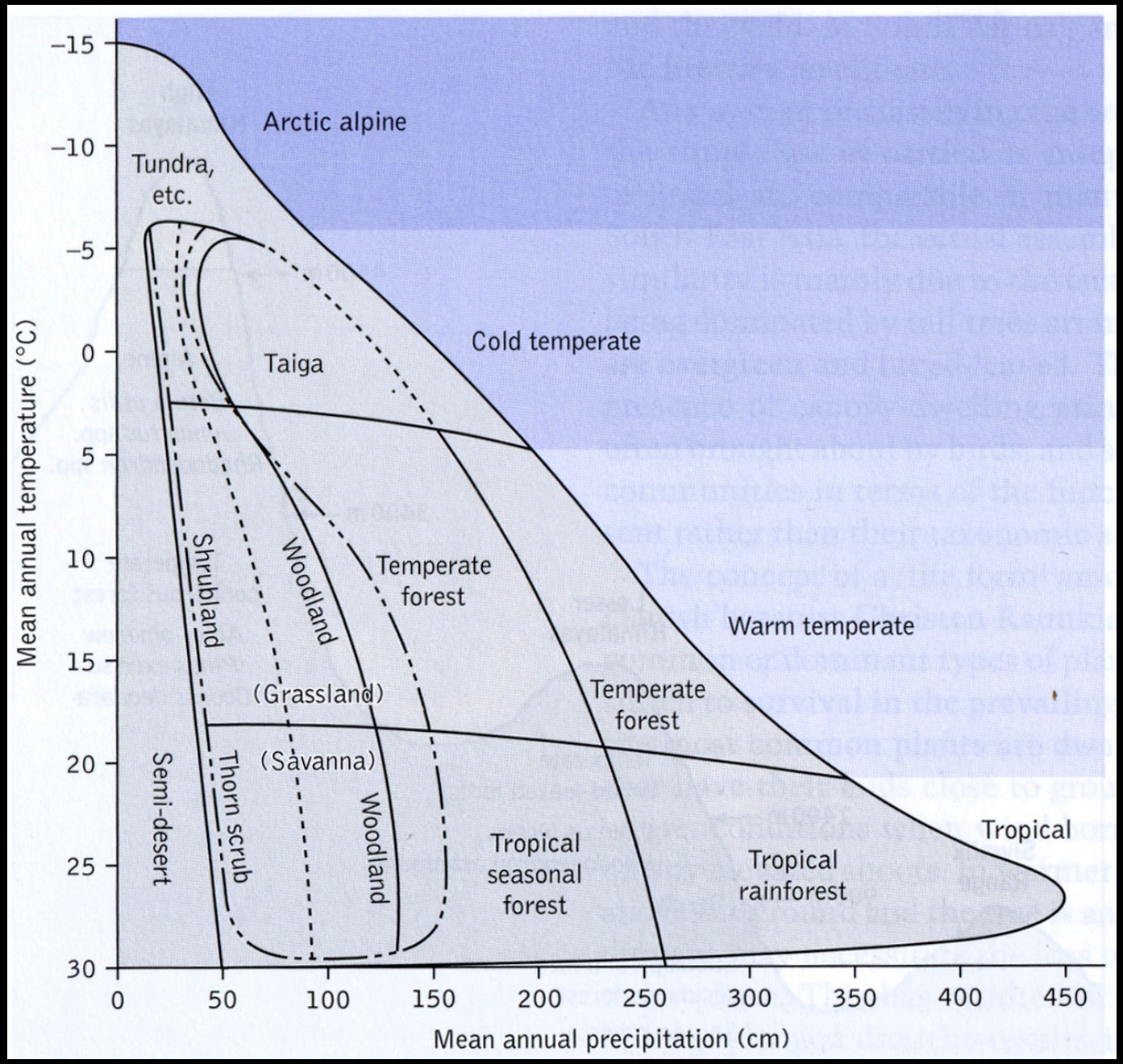
k. Curva de temp. médias mens.

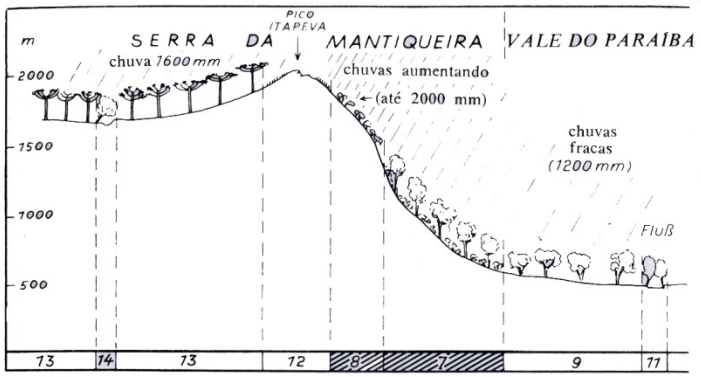
l. Curva de precip. média mens.

m. Curva de precip. Supl.

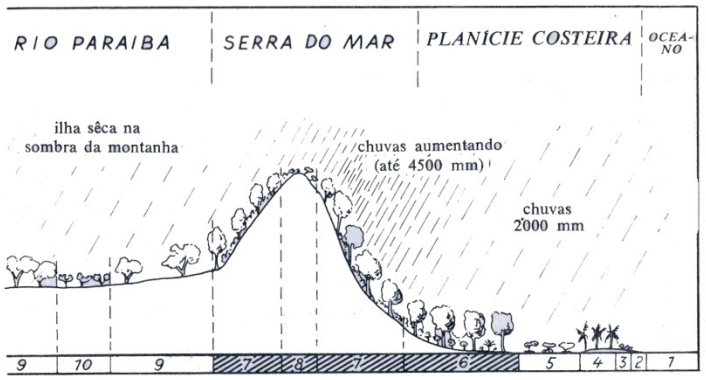
s. Duração média do periodo de congelemanto

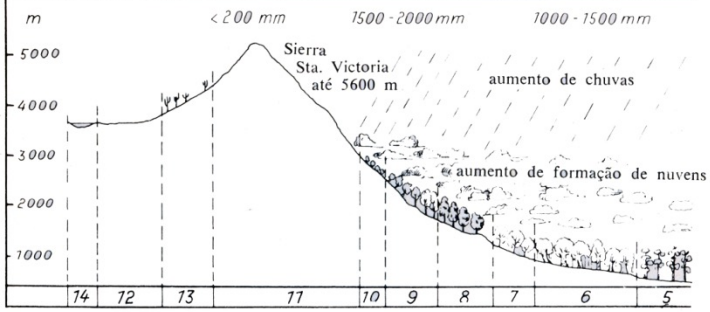

Tundra (Iceland)
-29.4
-40.6
162
Steppe (Afghanistan)
-7.4
-25.8
Boreal forest (Russia)
124
-14.6
-40.8
Chaparral (South Africa)
8.5
-0.3
Temperate deciduous forest (eastern USA)
-1.7
-26.1
Desert (Iraq)
4.0
-7.7
Alpine tundra (Switzerland)
-11.4
-31.5
Warm temperate evergreen forest (Argentina)
-5.8
-5.4
Savanna (Zimbabwe)
6.7
0.0
Tropical rainforest (Sri Lanka)
~6.0
21.8
16.6
Very wet season
Relatively humid season
Relative period of drought
Late or early frosts occur


Arctic alpine
Tundra, etc.
Cold temperate
Taiga
Warm temperate
Shrubland
Woodland
Temperate forest
(Grassland)
Temperate forest
(Savanna)
Thorn scrub
Woodland
Semi-desert
Tropical seasonal forest
Tropical rainforest
Tropical
Mean annual temperature (°C)
−15
−10
−5
0
5
10
15
20
25
30
0
50
100
150
200
250
300
350
400
450
Mean annual precipitation (cm)

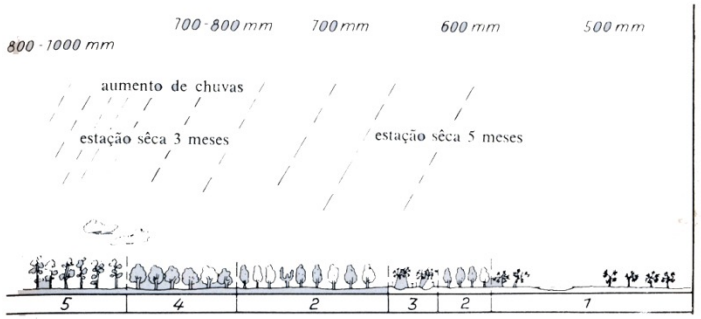


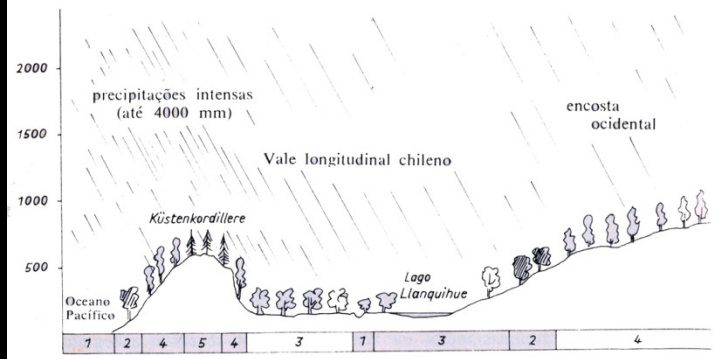
87a e b. Perfil da vegetação no leste de São Paulo: planície costeira, Serra do Mar, Vale do Paraíba, Serra da Mantiqueira. 1, **mar;** 2, **praia, pobre em vegetação;** 3, **dunas com arbustos;** 4, **mata de restinga com** Arecastrum romanzoffianum; 5, **manguezal em baías paradas;** 6, **mata pluvial na planície costeira;** 7, **mata pluvial da Serra do Mar nas partes inferiores das encostas;** 8, **mata de neblina (mata pluvial superior), limite inferior na Serra do Mar a 1.200 m, na Serra da Mantiqueira 1.300-1.400 m;** 9, **mata semi-sêca do Vale do Paraíba, atualmente destruída;** 10, **cerrados;** 11, **mata de inundação do Paraíba;** 12, **campos de altitude;** 13, **mata de** Araucaria **na sombra pluvial da Mantiqueira;** 14, **mata de Podocarpus ao longo dos riachos.**



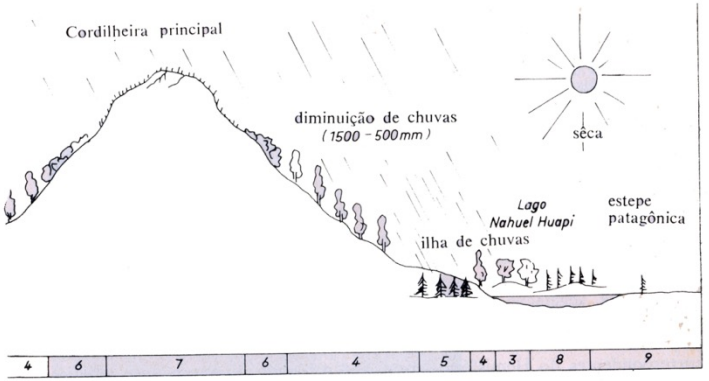


49a e b. A estratificação altitudinal das comunidades florestais da região de matas tucumano-bolivianas no noroeste da Argentina, entre 23 e 24°. 1-3 = matas do Chaco: 1, **tipo de "algarrobo" nas proximidades de uma depressão salgada;** 2, **tipo "quebracho";** 3, **tipo** Copernicia; 4-5, **matas de transição:** 4, **tipo "tala-mistol";** 5, **tipo** Calycophyllum; 6-10, **matas de altitude;** 6, **tipo "Laurel";** 7, **tipo mirtácea;** 8, **tipo "nogal-pino";** 9, **tipo "alisio";** 10, **tipo "queñoa" (mata de Polylepis);** 11-14: **vegetação das altitudes:** 11, **comunidades de gramíneas e vegetação de rochas dos Andes;** 12, **comunidades de gramíneas e arbustos da "puna";** 13, **cactáceas arbóreas;** 14, **depressões salgadas andinas.**



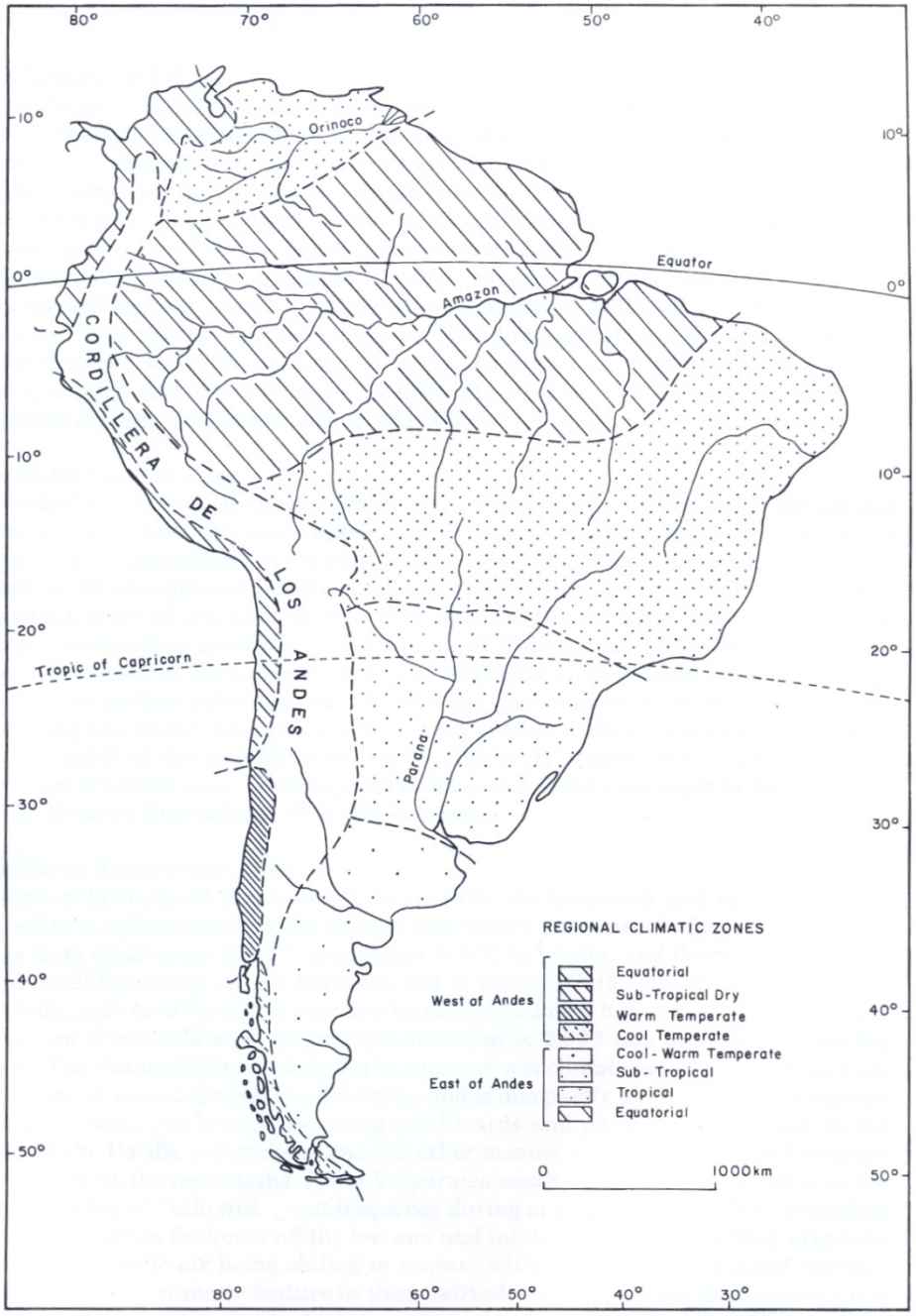


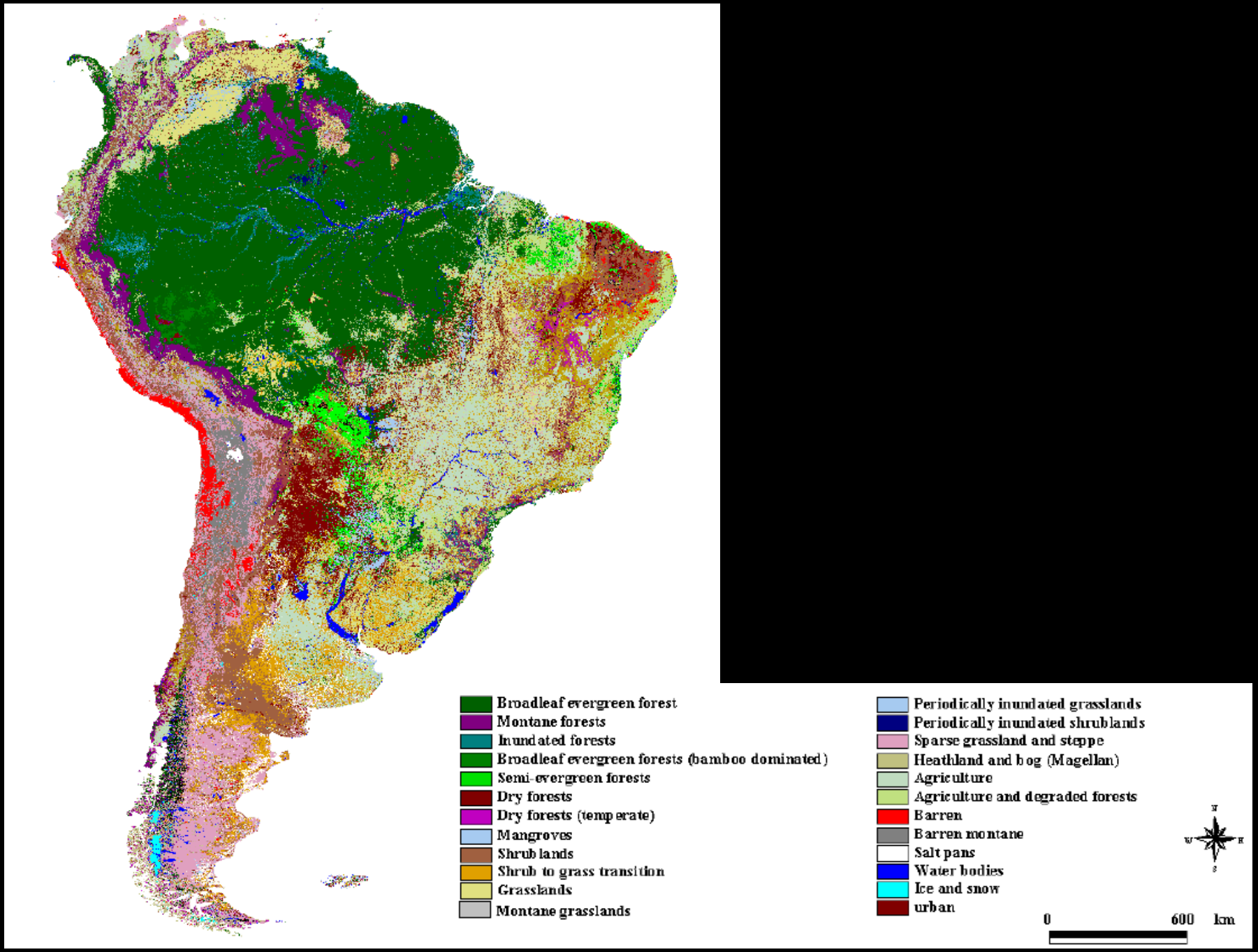
208. Perfil esquemático da cobertura florestal na Cordilheira costeira, no vale longitudinal chileno e na Cordilheira principal, cêrca de 41°. 1, **floresta de "boldo", com** Peumus boldus; 2, **mata pluvial valdiviana;** 3, **floresta de "roble-rauli";** 4, **floresta de "coihue";** 5, **floresta de** Fitzroya; 6, **vegetação arbustiva terminal de** Nothofagus pumilio **e** N. antarctica; 7, **comunidades de gramíneas alto-andinas;** 8, **floresta de** Libocedrus chilensis; 9, **estepe patagônica e restos de florestas de** Libocedrus



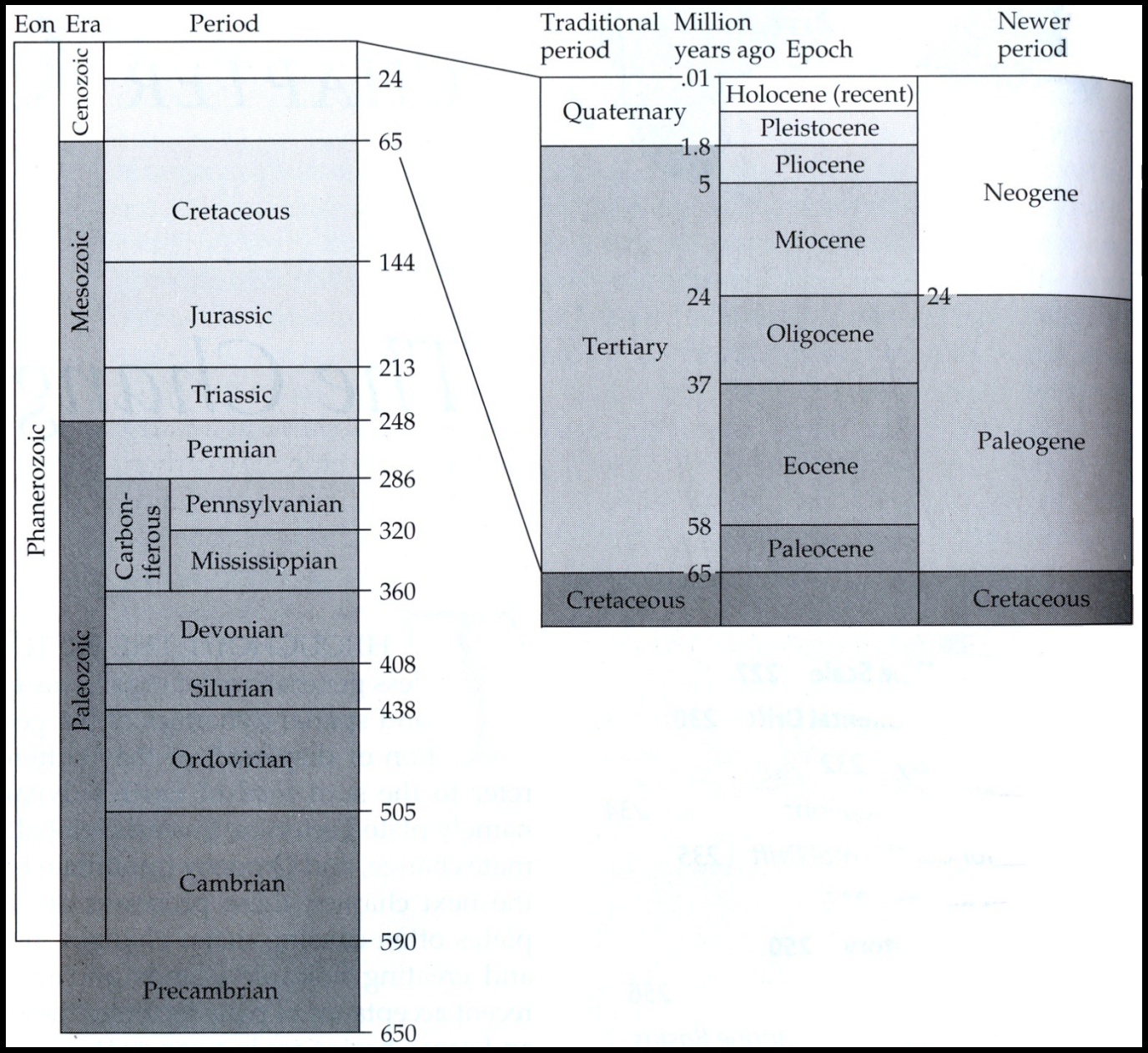
VEGETATIONSKARTE VON SÜDAMERIKA

von Kurt Hueck

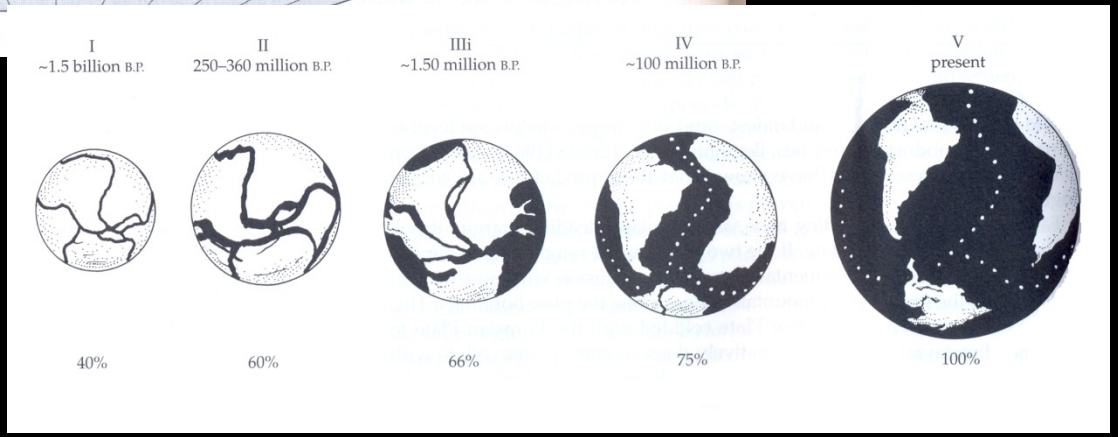


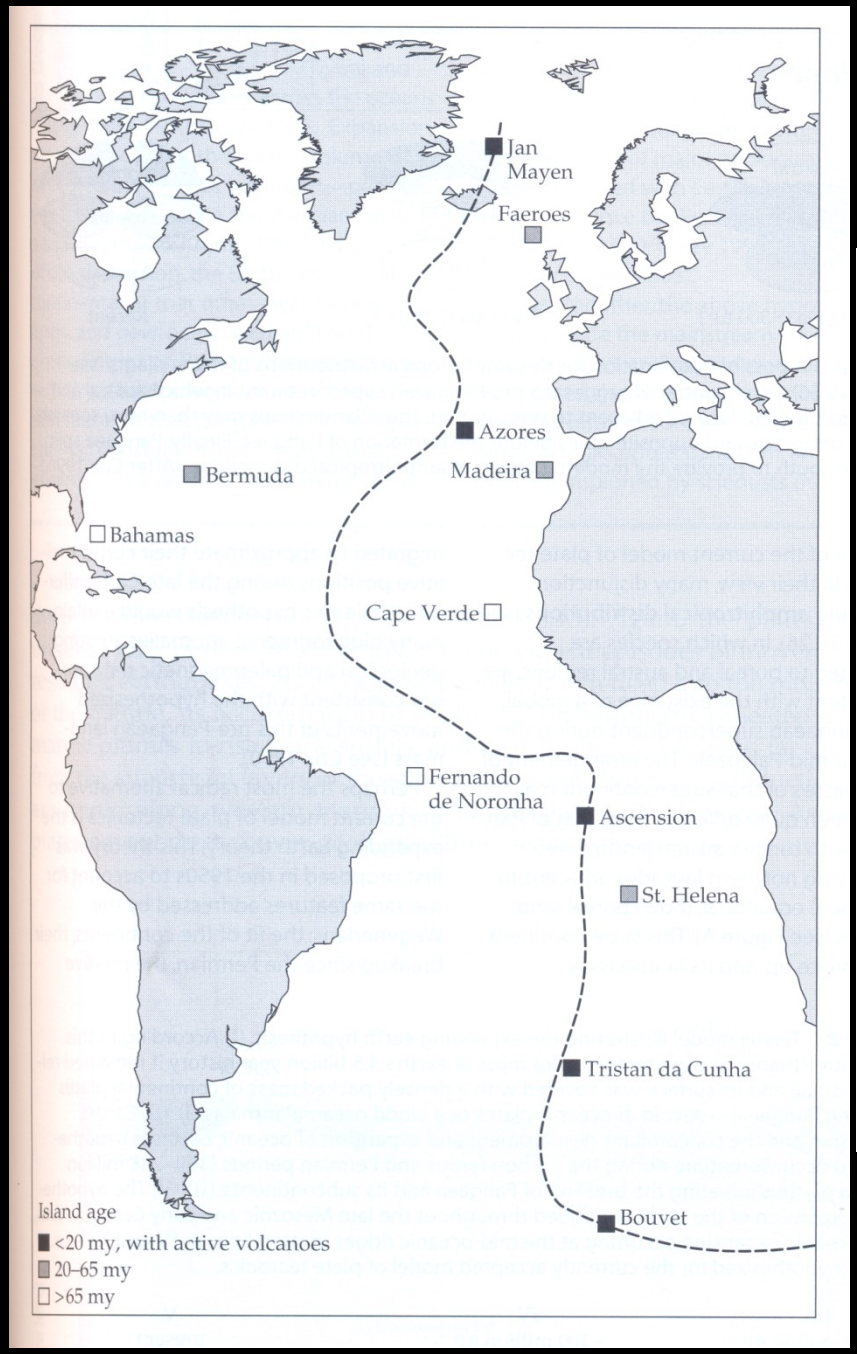

Broadleaf evergreen forest
Montane forests
Inundated forests
Broadleaf evergreen forests (bamboo dominated)
Semi-evergreen forests
Dry forests
Dry forests (temperate)
Mangroves
Shrublands
Shrub to grass transition
Grasslands
Montane grasslands
Periodically inundated grasslands
Periodically inundated shrublands
Sparse grassland and steppe
Heathland and bog (Magellan)
Agriculture
Agriculture and degraded forests
Barren
Barren montane
Salt pans
Water bodies
Ice and snow
urban
N
W
E
S
0
600
km

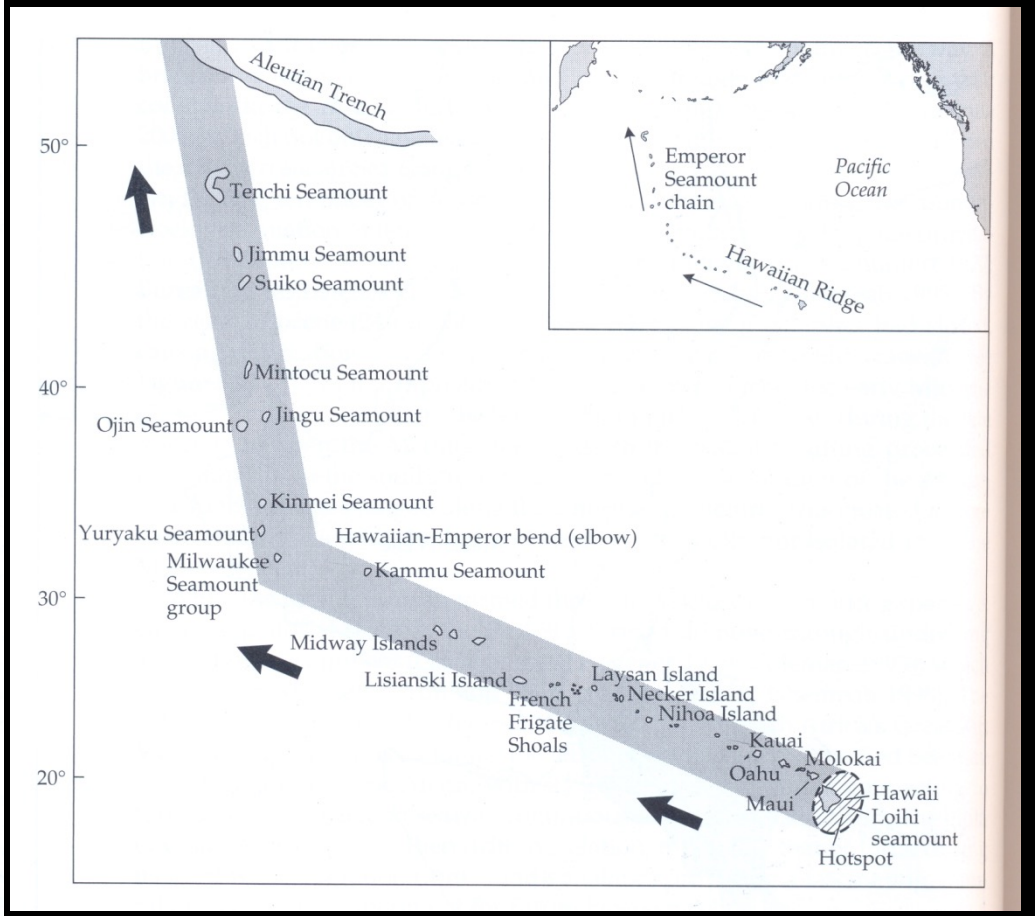

Llanos
Choco
Gran Sabana
Rio Negro
Marajó
Pastaza
Amazon
Caatingas
Acre
Llanos of Moxos
Pantanal
Cerrado
Altiplano
Chaco
Pampa
Valdivia
Patagonia

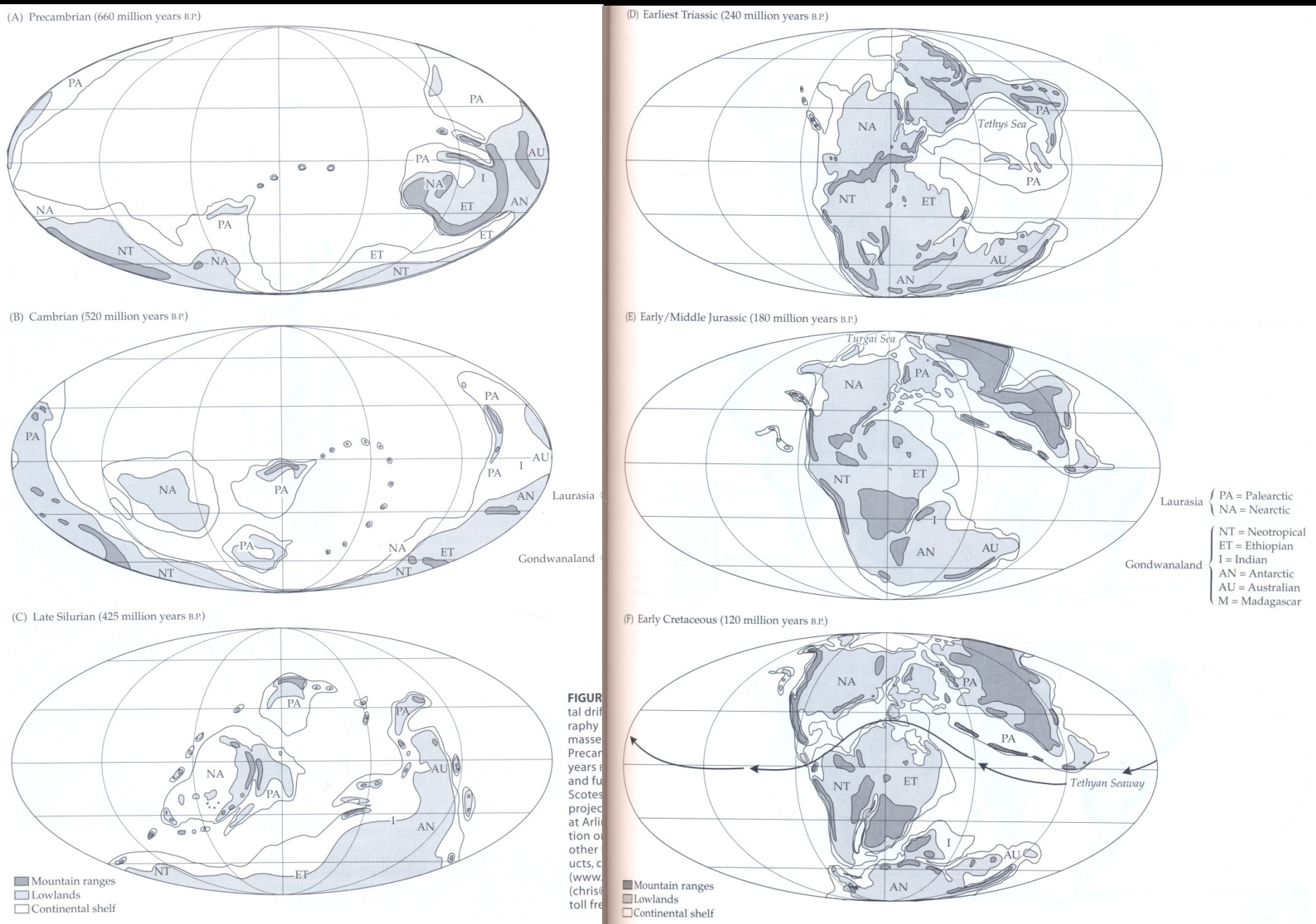

Eon
Era
Period
Phanerozoic
Cenozoic
Mesozoic
Paleozoic
Cretaceous
Jurassic
Triassic
Permian
Carbon-iferous
Pennsylvanian
Mississippian
Devonian
Silurian
Ordovician
Cambrian
Precambrian
24
65
144
213
248
286
320
360
408
438
505
590
650
Traditional period
Million years ago
Epoch
Newer period
.01
1.8
5
24
37
58
65
Quaternary
Tertiary
Cretaceous
Holocene (recent)
Pleistocene
Pliocene
Miocene
Oligocene
Eocene
Paleocene
Neogene
Paleogene
Cretaceous

Tectônica de placas e Orogênese dos Andes




Jan Mayen
Faeroes
Azores
Bermuda
Madeira
Bahamas
Cape Verde
Fernando de Noronha
Ascension
St. Helena
Tristan da Cunha
Bouvet
Island age
<20 my, with active volcanoes
20–65 my
>65 my


Aleutian Trench
50°
40°
30°
20°
Tenchi Seamount
Jimmu Seamount
Suiko Seamount
Mintocu Seamount
Ojin Seamount
Jingu Seamount
Kinmei Seamount
Yuryaku Seamount
Hawaiian-Emperor bend (elbow)
Milwaukee Seamount group
Kammu Seamount
Midway Islands
Lisianski Island
Laysan Island
Necker Island
French Frigate Shoals
Nihoa Island
Kauai
Oahu
Molokai
Maui
Hawaii
Loihi seamount
Hotspot
Emperor Seamount chain
Pacific Ocean
Hawaiian Ridge



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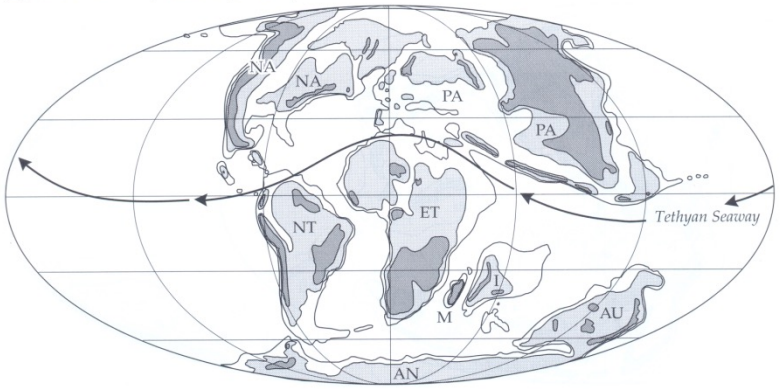
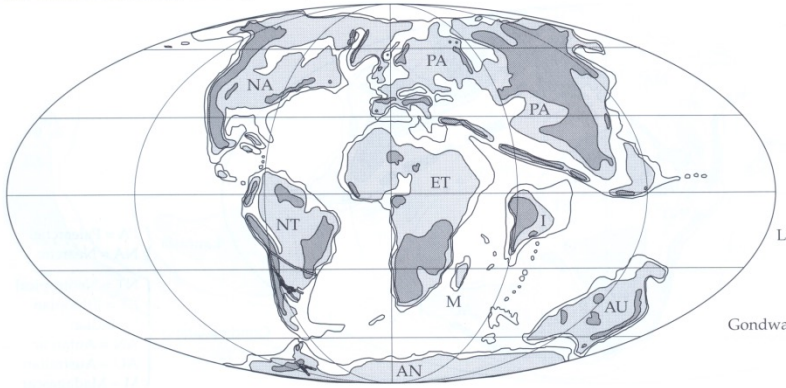
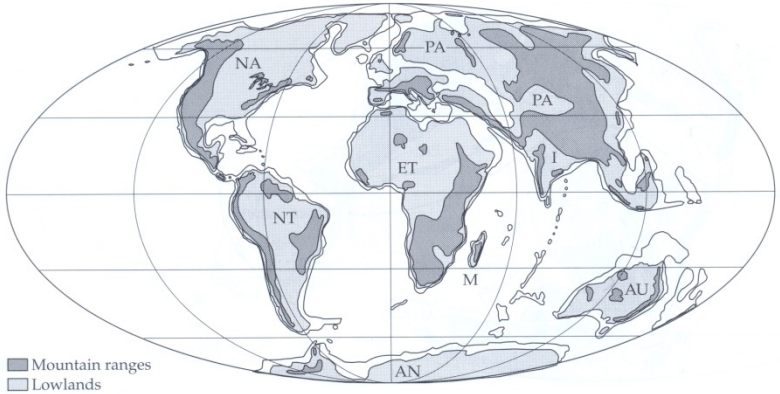
(G) Late Cretaceous (80 million years B.P.)



(H) Middle Paleocene (60 million years B.P.)



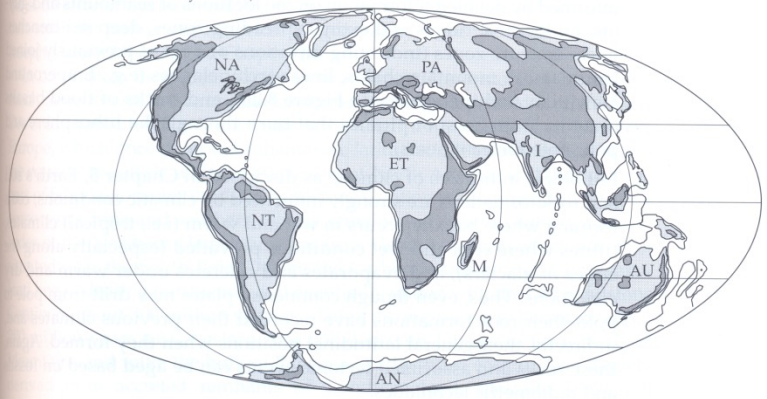
(I) Early Oligocene (30 million years B.P.)



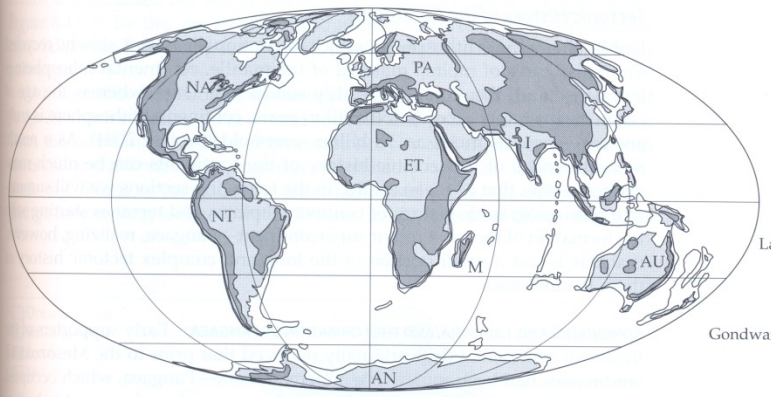
Mountain ranges
Lowlands
Continental shelf

Laurasia
Gondwanaland

(J) Late Miocene (10 million years B.P.)



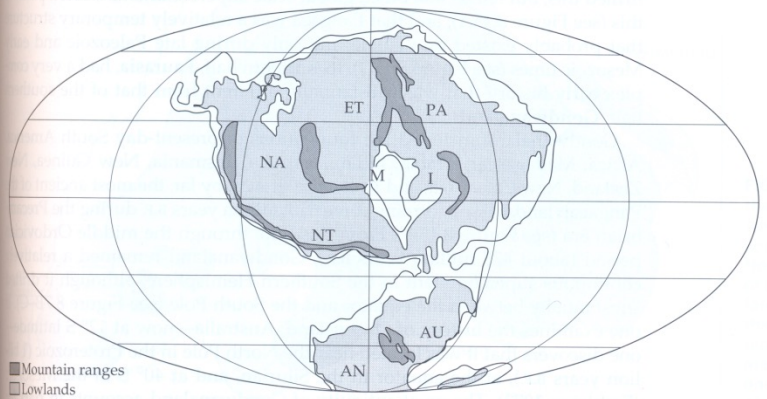
(K) Present day



Laurasia
- PA = Palearctic
- NA = Nearctic

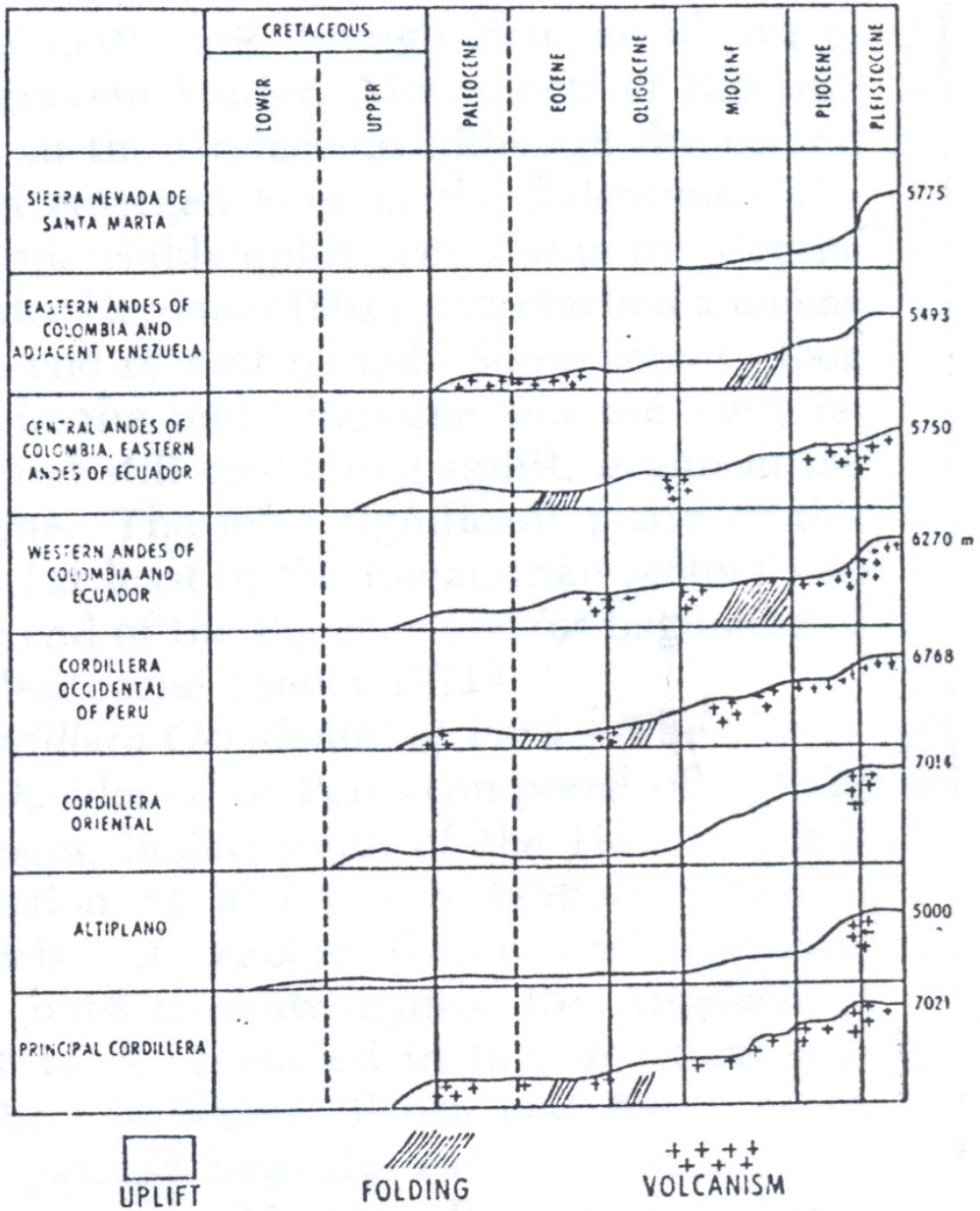
Gondwanaland
- NT = Neotropical
- ET = Ethiopian
- I = Indian
- AN = Antarctic
- AU = Australian
- M = Madagascar

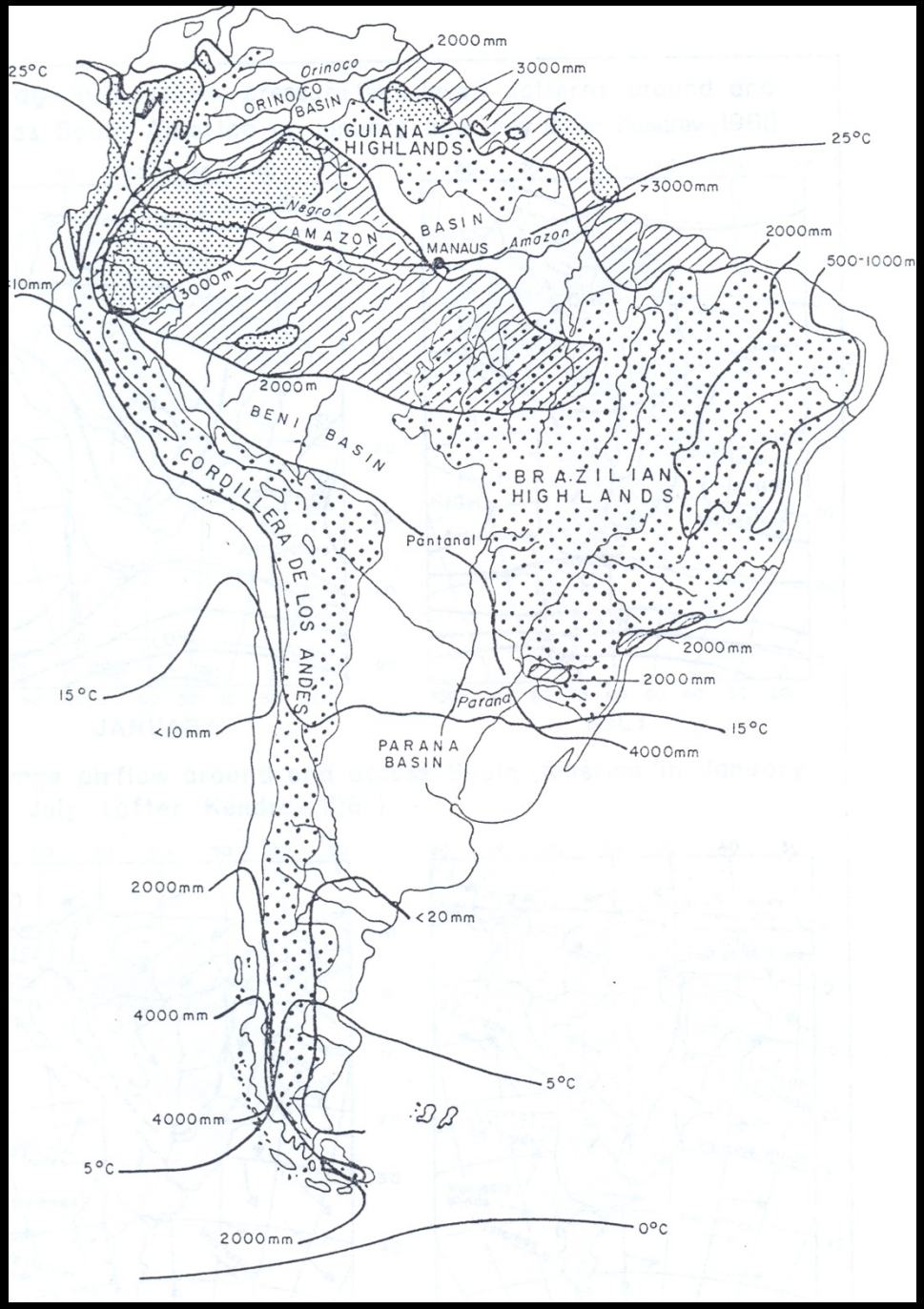
(L) Future (+250 million years)

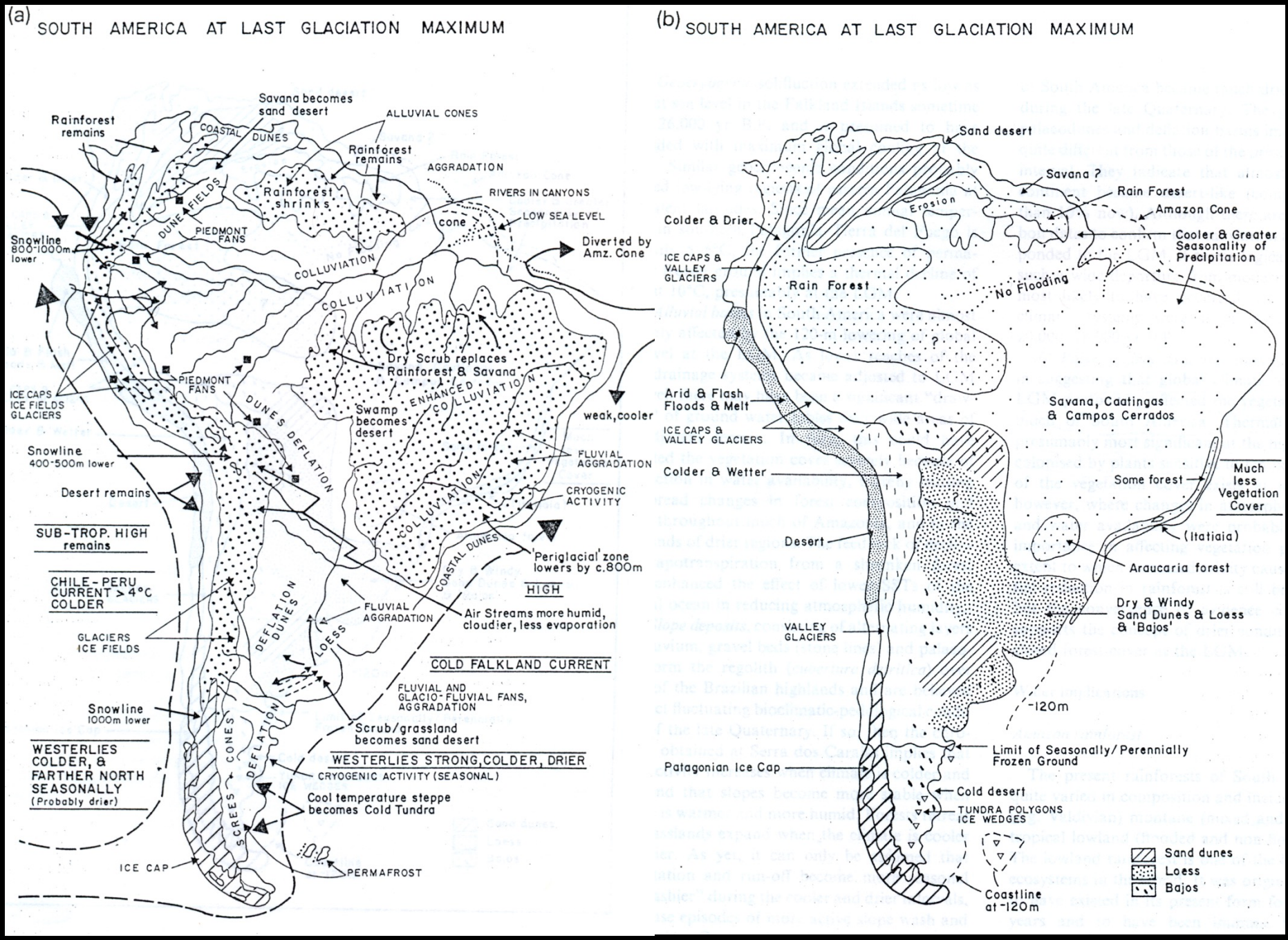


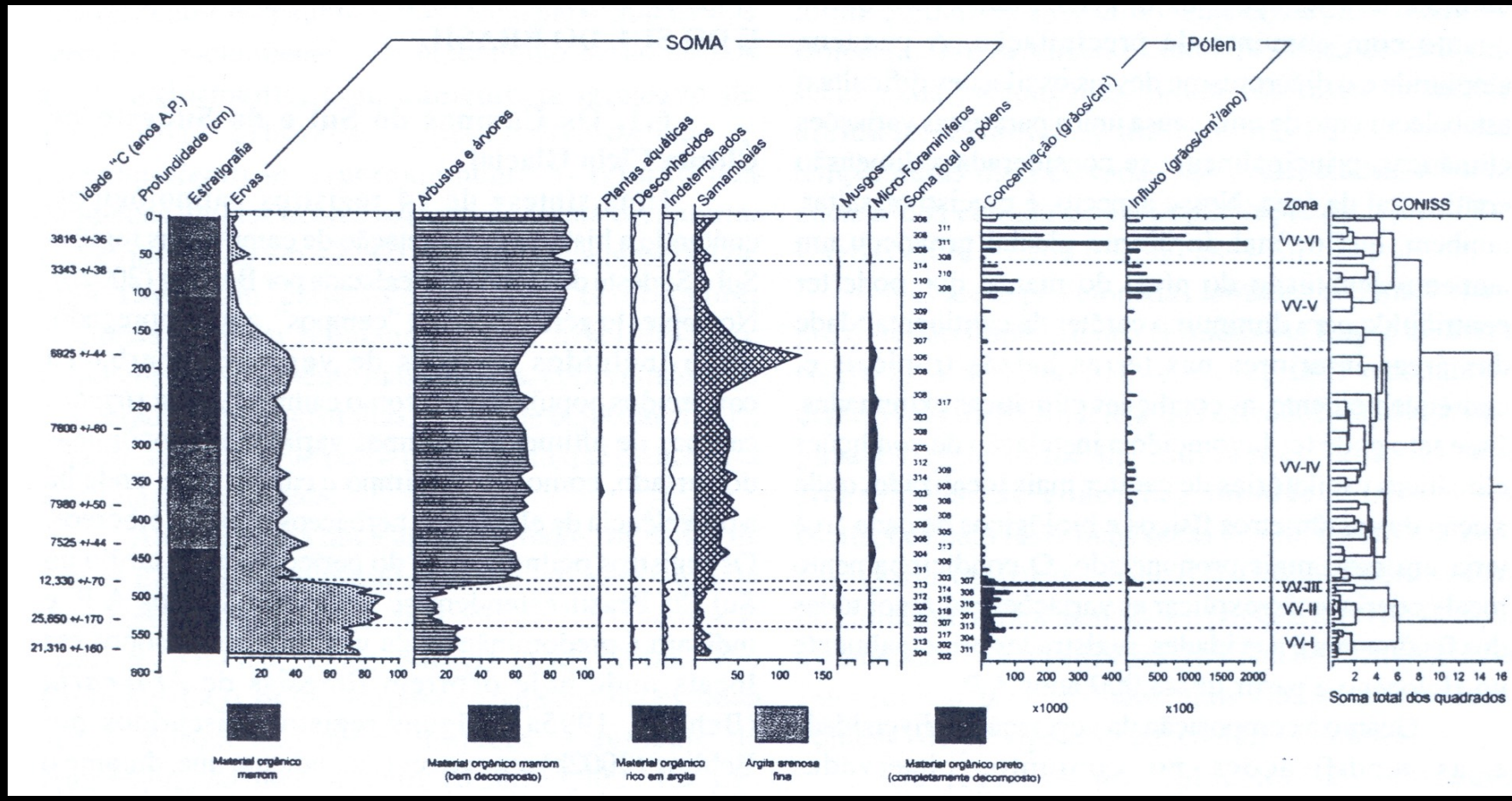
Mountain ranges
Lowlands
Continental shelf

TECTONIC HISTORY OF THE TROPICAL ANDES (SCHEMATIC)

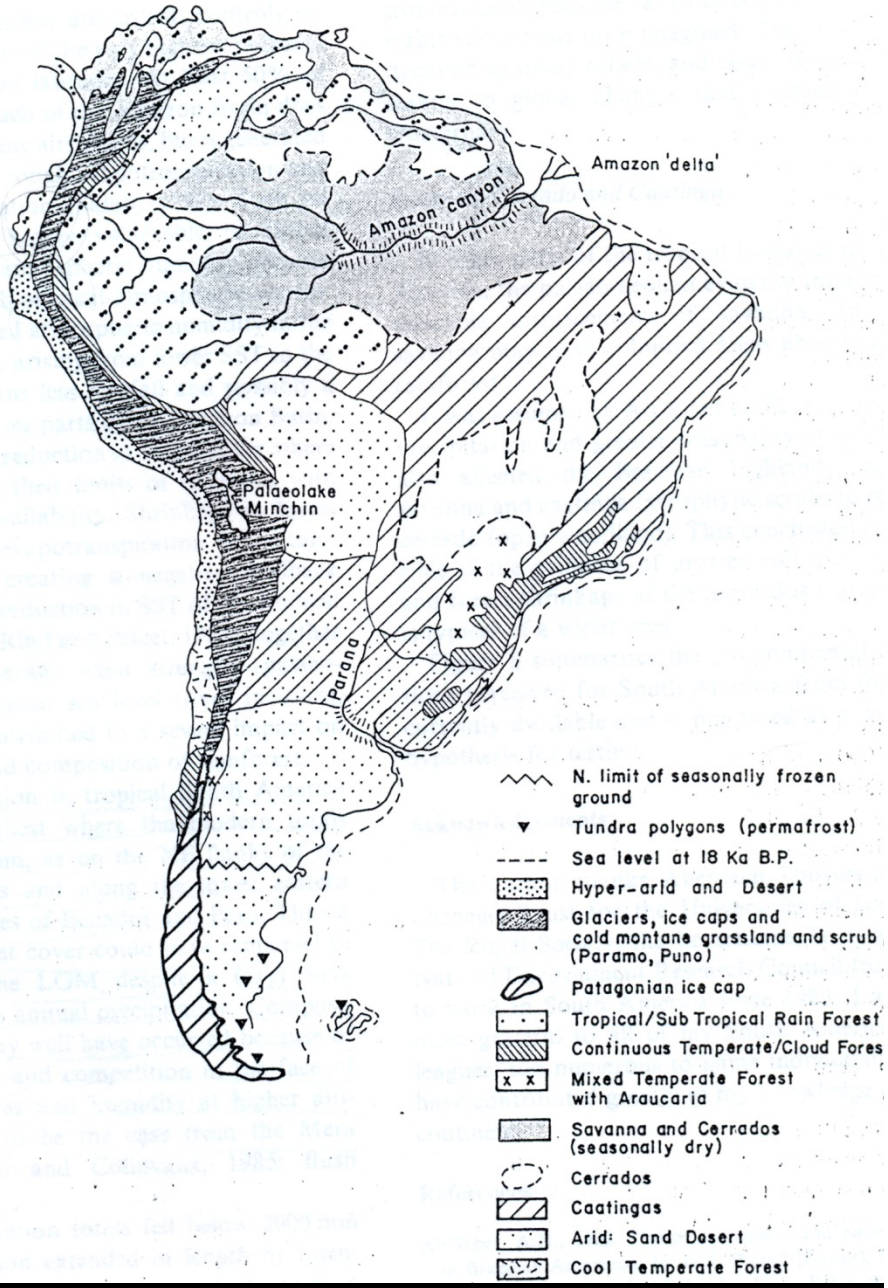



2000 mm
3000mm
25°C
Orinoco
ORINOCO BASIN
GUIANA HIGHLANDS
25°C
>3000mm
Negro
AMAZON BASIN
MANAUS
Amazon
2000mm
500-1000m
3000m
2000m
BENI BASIN
CORDILLERA DE LOS ANDES
BRAZILIAN HIGHLANDS
Pantanal
2000 mm
15°C
2000 mm
Parana
<10 mm
15°C
PARANA BASIN
4000mm
2000mm
<20mm
4000 mm
5°C
4000mm
5°C
2000mm
0°C


(a) SOUTH AMERICA AT LAST GLACIATION MAXIMUM
Savana becomes sand desert
ALLUVIAL CONES
Rainforest remains
COASTAL DUNES
Rainforest remains
AGGRADATION
Rainforest shrinks
RIVERS IN CANYONS
DUNE FIELDS
cone
LOW SEA LEVEL
PIEDMONT FANS
Snowline 800-1000m lower
Diverted by Amz. Cone
COLLUVIATION
COLLUVIATION
Dry Scrub replaces Rainforest & Savana
PIEDMONT FANS
ICE CAPS ICE FIELDS GLACIERS
ENHANCED COLLUVIATION
DUNES DEFLATION
Swamp becomes desert
weak, cooler
Snowline 400-500m lower
FLUVIAL AGGRADATION
Desert remains
CRYOGENIC ACTIVITY
COLLUVIATION
SUB-TROP. HIGH remains
COASTAL DUNES
'Periglacial' zone lowers by c.800m
CHILE-PERU CURRENT > 4°C COLDER
HIGH
FLUVIAL AGGRADATION
Air Streams more humid, cloudier, less evaporation
GLACIERS ICE FIELDS
DEFLATION DUNES
LOESS
COLD FALKLAND CURRENT
FLUVIAL AND GLACIO-FLUVIAL FANS, AGGRADATION
Snowline 1000m lower
Scrub/grassland becomes sand desert
WESTERLIES COLDER, & FARTHER NORTH SEASONALLY (Probably drier)
WESTERLIES STRONG, COLDER, DRIER
CRYOGENIC ACTIVITY (SEASONAL)
SCREES
CONES
DEFLATION
Cool temperature steppe becomes Cold Tundra
ICE CAP
PERMAFROST
(b) SOUTH AMERICA AT LAST GLACIATION MAXIMUM
Sand desert
Savana ?
Rain Forest
Erosion
Amazon Cone
Colder & Drier
Cooler & Greater Seasonality of Precipitation
ICE CAPS & VALLEY GLACIERS
Rain Forest
No Flooding
?
Arid & Flash Floods & Melt
Savana, Caatingas & Campos Cerrados
ICE CAPS & VALLEY GLACIERS
Colder & Wetter
Much less Vegetation Cover
Some forest
(Itatiaia)
Desert
Araucaria forest
Dry & Windy Sand Dunes & Loess & 'Bajos'
VALLEY GLACIERS
-120m
Limit of Seasonally/Perennially Frozen Ground
Patagonian Ice Cap
Cold desert
TUNDRA POLYGONS ICE WEDGES
Sand dunes
Loess
Bajos
Coastline at -120m

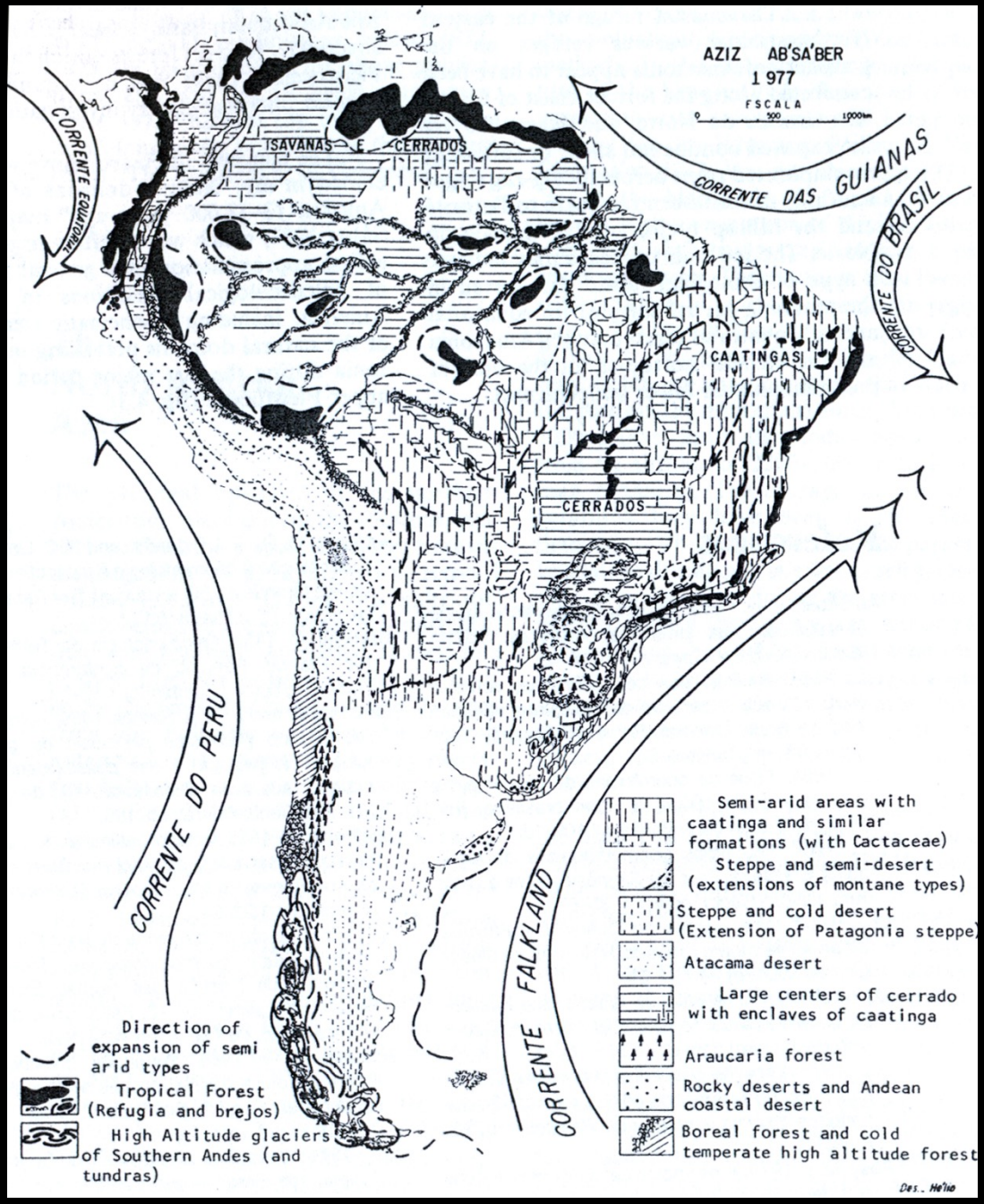

SOMA
Pólen
Idade 14C (anos A.P.)
Profundidade (cm)
Estratigrafia
Ervas
Arbustos e árvores
Plantas aquáticas
Desconhecidos
Indeterminados
Samambaias
Musgos
Micro-Foraminíferos
Soma total de pólens
Concentração (grãos/cm³)
Influxo (grãos/cm²/ano)
Zona
CONISS
3816 +/-36
3343 +/-38
6825 +/-44
7800 +/-60
7980 +/-50
7525 +/-44
12,330 +/-70
25,650 +/-170
21,310 +/-160
VV-VI
VV-V
VV-IV
VV-III
VV-II
VV-I
x1000
x100
Soma total dos quadrados
Material orgânico marrom
Material orgânico marrom (bem decomposto)
Material orgânico rico em argila
Argila arenosa fina
Material orgânico preto (completamente decomposto)

SOUTH AMERICA AT LAST GLACIATION MAXIMUM

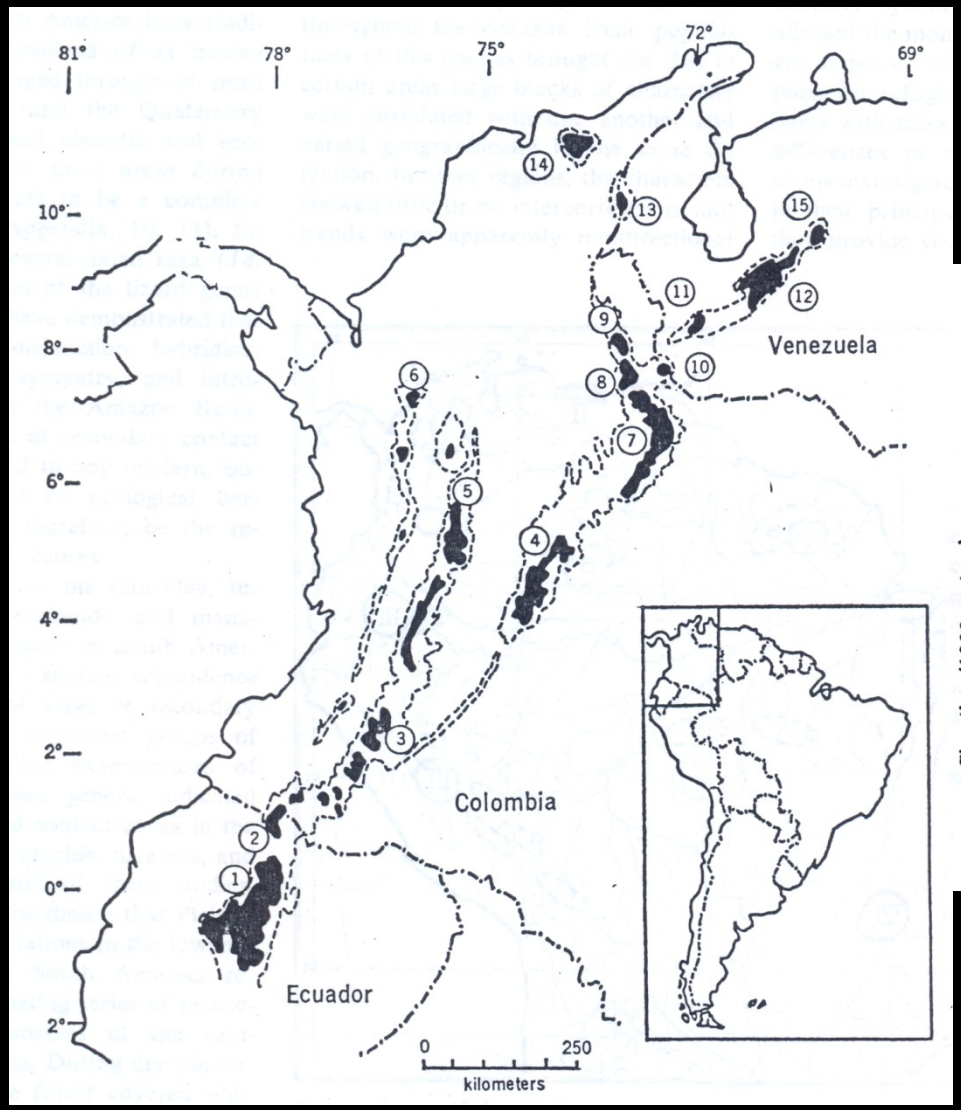


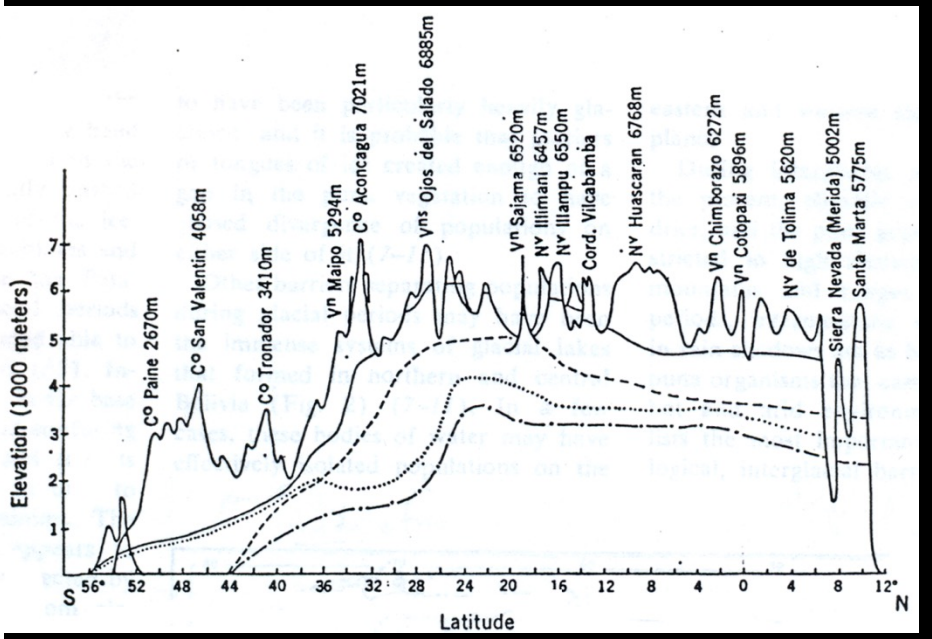
VEGETATIONSKARTE VON SÜDAMERIKA

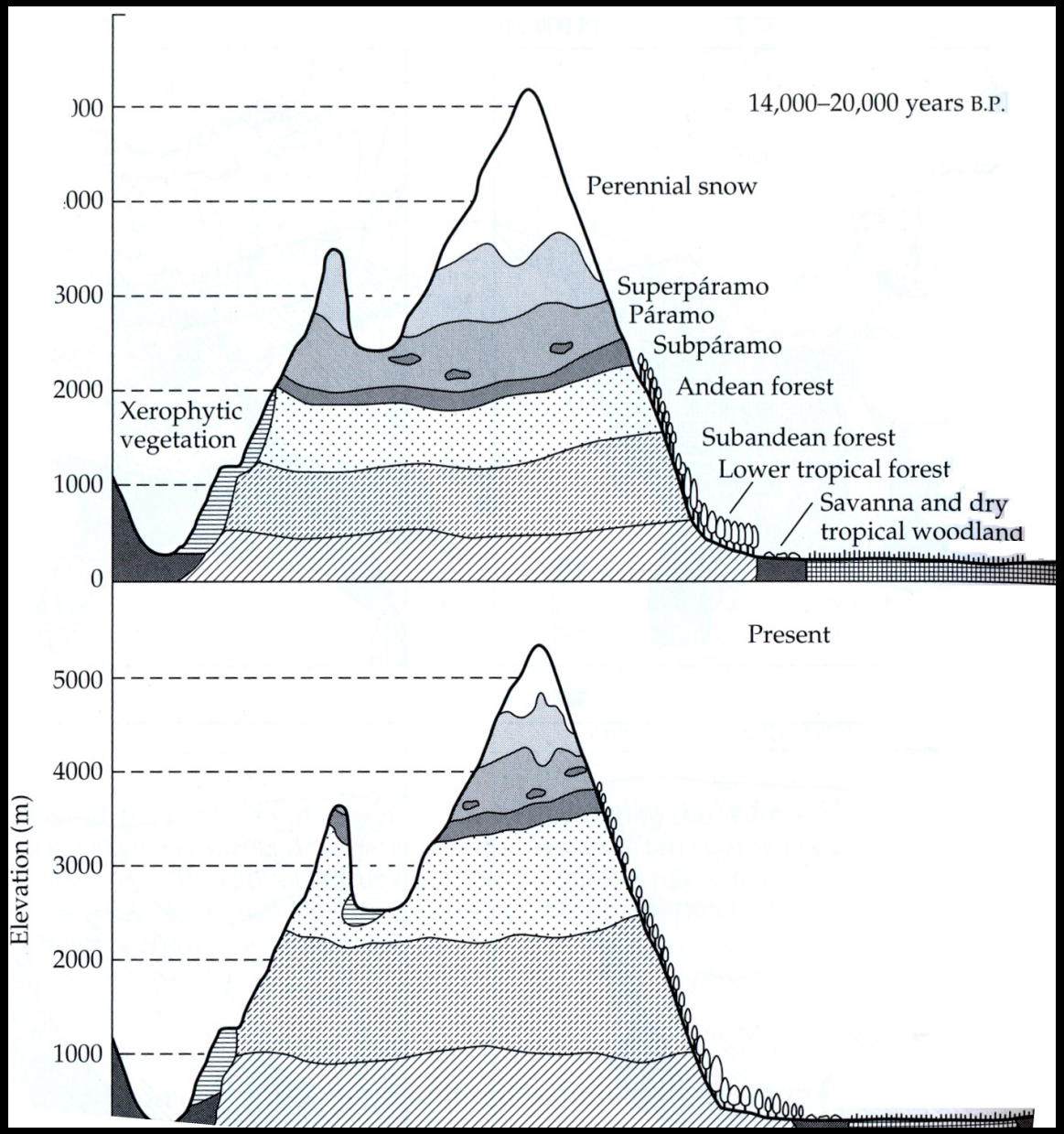
von Kurt Hueck

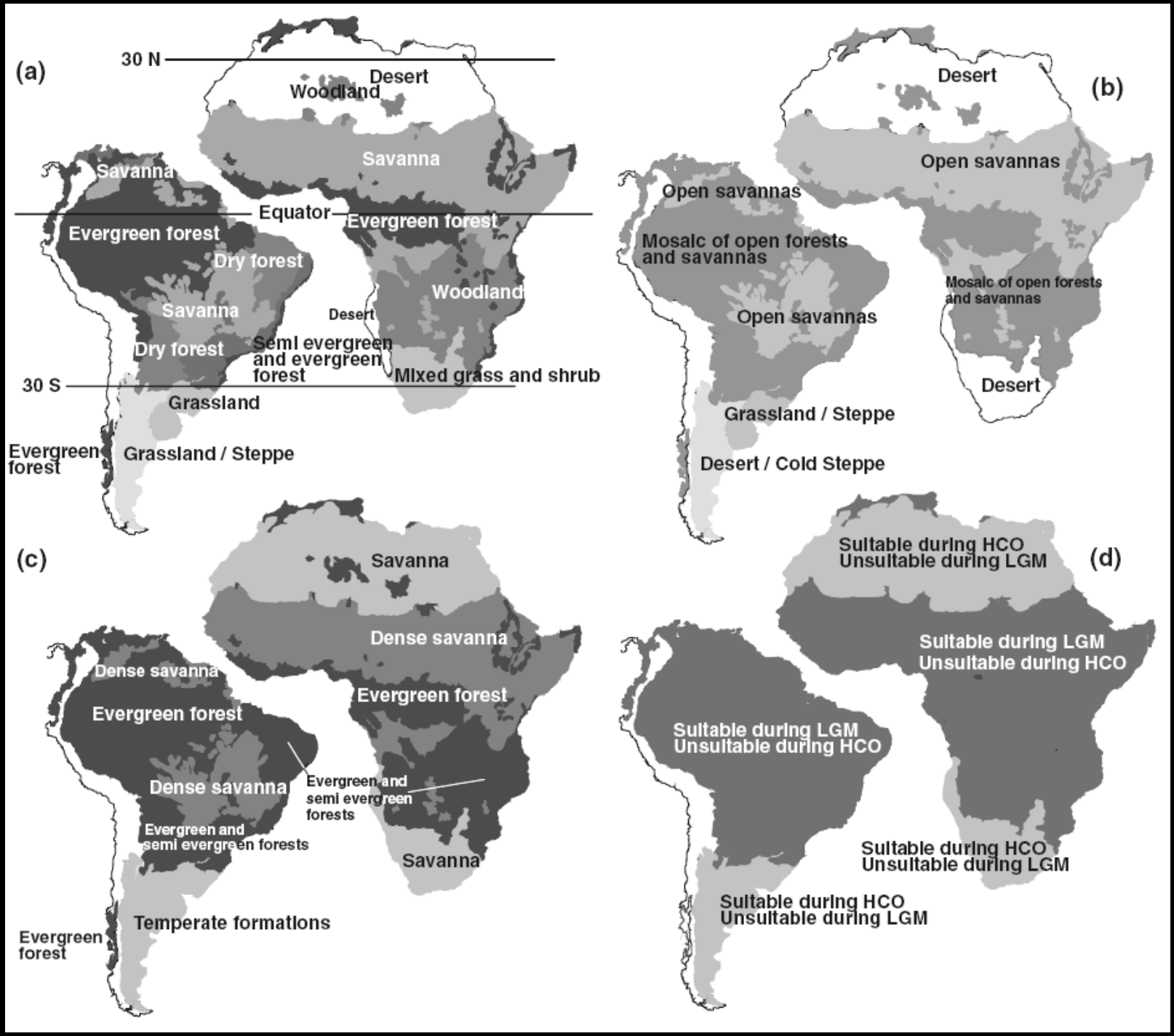

AZIZ AB'SA'BER
1 977
FSCALA
0 500 1000km
CORRENTE EQUATORIAL
CORRENTE DAS GUIANAS
CORRENTE DO BRASIL
CORRENTE DO PERU
CORRENTE FALKLAND
SAVANAS E CERRADOS
CAATINGAS
CERRADOS
Semi-arid areas with caatinga and similar formations (with Cactaceae)
Steppe and semi-desert (extensions of montane types)
Steppe and cold desert (Extension of Patagonia steppe)
Atacama desert
Large centers of cerrado with enclaves of caatinga
Araucaria forest
Rocky deserts and Andean coastal desert
Boreal forest and cold temperate high altitude forest
Direction of expansion of semi arid types
Tropical Forest (Refugia and brejos)
High Altitude glaciers of Southern Andes (and tundras)
Des. Heine

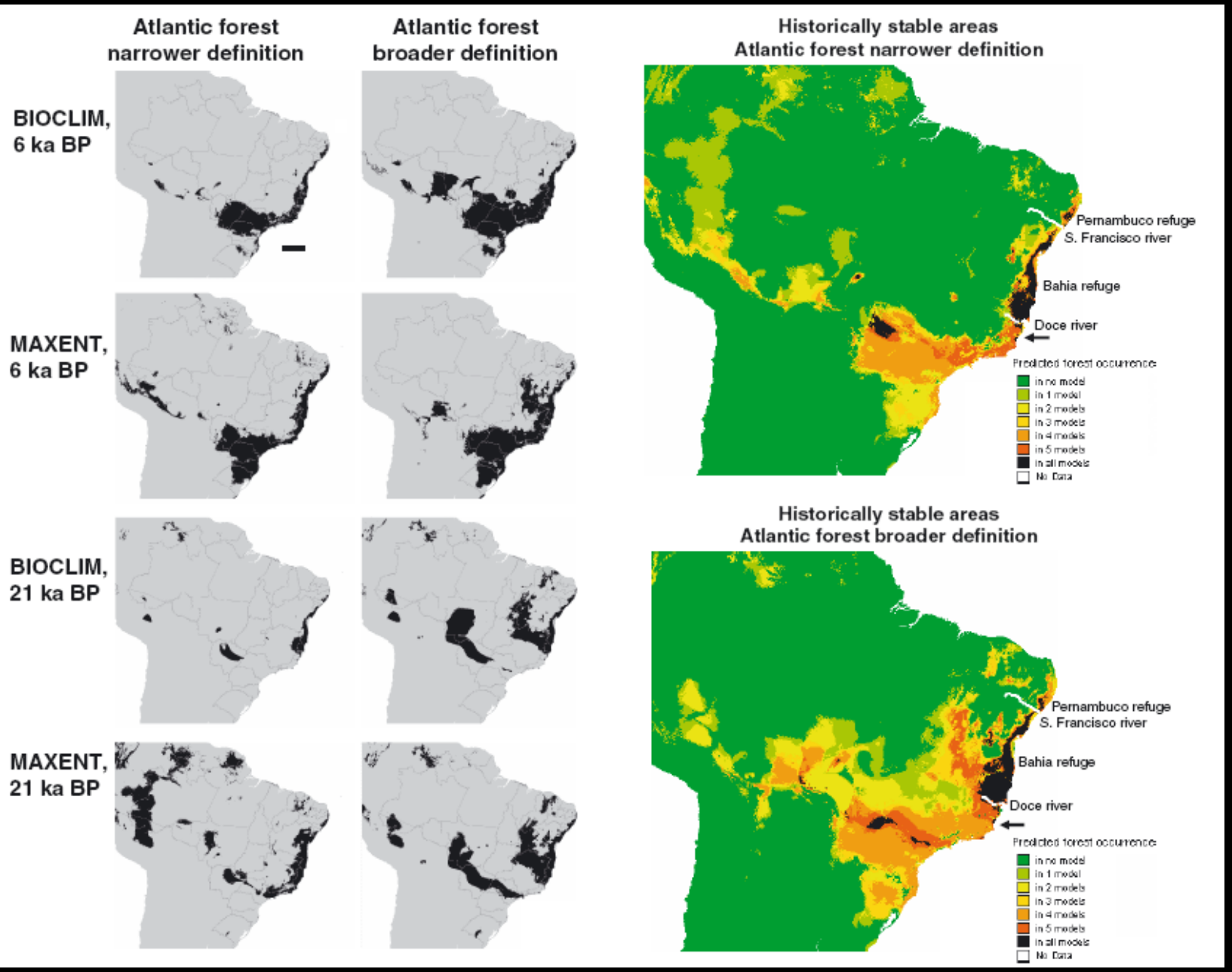

Glacial ice
Glacial lakes

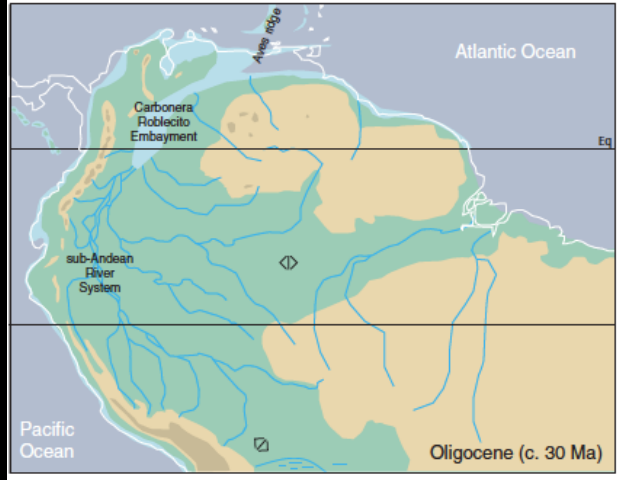

81°
78°
75°
72°
69°
10°
8°
6°
4°
2°
0°
2°
Venezuela
Colombia
Ecuador
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
0
250
kilometers


Elevation (1000 meters)
1
2
3
4
5
6
7
Cº Paine 2670m
Cº San Valentin 4058m
Cº Tronador 3410m
Vn Maipo 5294m
Cº Aconcagua 7021m
Vns Ojos del Salado 6885m
Vn Sajama 6520m
Nv Illimani 6457m
Nv Illampu 6550m
Cord. Vilcabamba
Nv Huascaran 6768m
Vn Chimborazo 6272m
Vn Cotopaxi 5896m
Nv de Tolima 5620m
Sierra Nevada (Merida) 5002m
Santa Marta 5775m
S
56°
52
48
44
40
36
32
28
24
20
16
12
8
4
0
4
8
12°
N
Latitude


14,000–20,000 years B.P.
Perennial snow
Superpáramo
Páramo
Subpáramo
Andean forest
Xerophytic vegetation
Subandean forest
Lower tropical forest
Savanna and dry tropical woodland
Present
Elevation (m)
5000
4000
3000
2000
1000
0


(a)
30 N
Desert
Woodland
Savanna
Savanna
Equator
Evergreen forest
Evergreen forest
Dry forest
Woodland
Savanna
Desert
Dry forest
Semi evergreen and evergreen forest
Mixed grass and shrub
30 S
Grassland
Evergreen forest
Grassland / Steppe
(b)
Desert
Open savannas
Open savannas
Mosaic of open forests and savannas
Mosaic of open forests and savannas
Open savannas
Desert
Grassland / Steppe
Desert / Cold Steppe
(c)
Savanna
Dense savanna
Dense savanna
Evergreen forest
Evergreen forest
Dense savanna
Evergreen and semi evergreen forests
Evergreen and semi evergreen forests
Savanna
Temperate formations
Evergreen forest
(d)
Suitable during HCO
Unsuitable during LGM
Suitable during LGM
Unsuitable during HCO
Suitable during LGM
Unsuitable during HCO
Suitable during HCO
Unsuitable during LGM
Suitable during HCO
Unsuitable during LGM

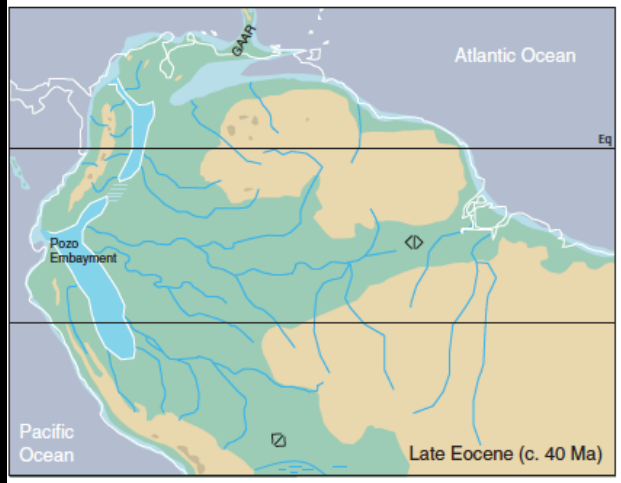

Atlantic forest narrower definition
Atlantic forest broader definition
BIOCLIM, 6 ka BP
MAXENT, 6 ka BP
BIOCLIM, 21 ka BP
MAXENT, 21 ka BP
Historically stable areas
Atlantic forest narrower definition
Pernambuco refuge
S. Francisco river
Bahia refuge
Doce river
Predicted forest occurrence
in no model
in 1 model
in 2 models
in 3 models
in 4 models
in 5 models
in all models
No Data
Historically stable areas
Atlantic forest broader definition
Pernambuco refuge
S. Francisco river
Bahia refuge
Doce river
Predicted forest occurrence
in no model
in 1 model
in 2 models
in 3 models
in 4 models
in 5 models
in all models
No Data



Oligocene (c. 24–34 Ma)

Uplift Central Cordillera (Central and Northern Andes)
Onset uplift Eastern Cordillera (Northern Andes)
Western Amazon lowland corridor
Tropical wet climate with intense dry season western Amazonia
South-north sub-Andean trunk river
Carbonate platforms along northern coasts South America
Major drainage divide in central-eastern Amazonia
Shield areas stable, some denudation

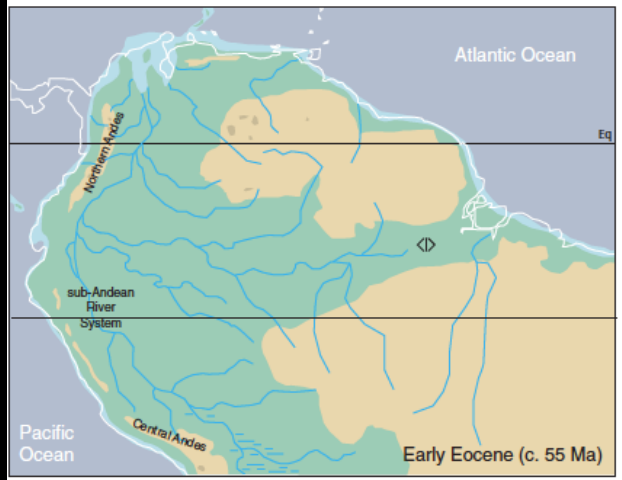
Intermediate diverse rainforest in northern Andes
Diverse tetrapod fauna in western Amazonia



Late Eocene (c. 34–43 Ma)

Uplift Central Cordillera (Central and Northern Andes)
Marine incursions in west, northwest and north
Greater Antilles-Aves (GAAR) Ridge between N and S America
Carbonate platforms along northern coasts South America
Major drainage divide in eastern Amazonia
Shield areas stable, deep weathering

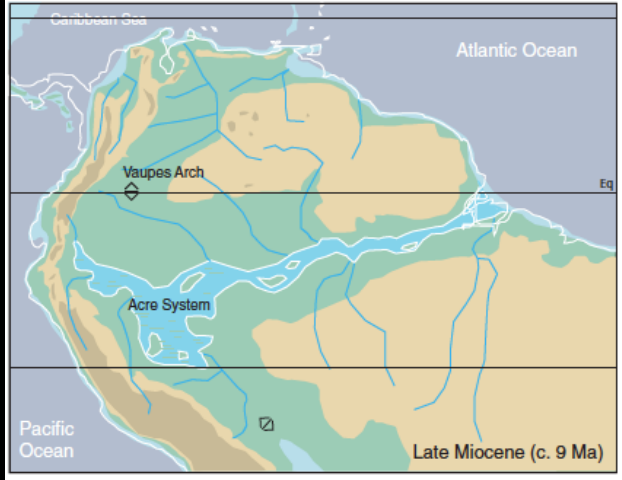
Hyperdiverse rainforest in northern Andes



Early Eocene (c. 43–59 Ma)

Uplift Central Cordillera (Central and Northern Andes)
South-north sub-Andean trunk river
Major Pantanal-type wetlands Bolivia
Major drainage divide in eastern Amazonia
Northward shift Paraná-Amazon drainage
Shield areas stable

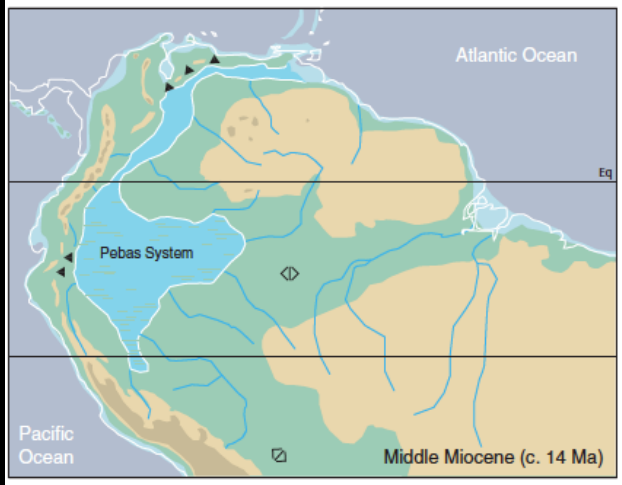
Rainforest diversification in northern Andes



Late Miocene (c. 7–11 Ma)

Accelerated uplift Central Andes
Uplift Eastern Cordillera and Mérida Andes (Northern Andes)
Fragmentation Northern Andean drainage systems
Uplift Western Amazon portal
Uplift Vaupes Arch, onset Orinoco-Amazon divide
Establishment transcontinental Amazon drainage system
Onset Amazon submarine fan
Acre fluvio-tidal megawetland in western Amazonia
Termination active carbonate platforms along NE South American coast
Shield areas stable, deep weathering

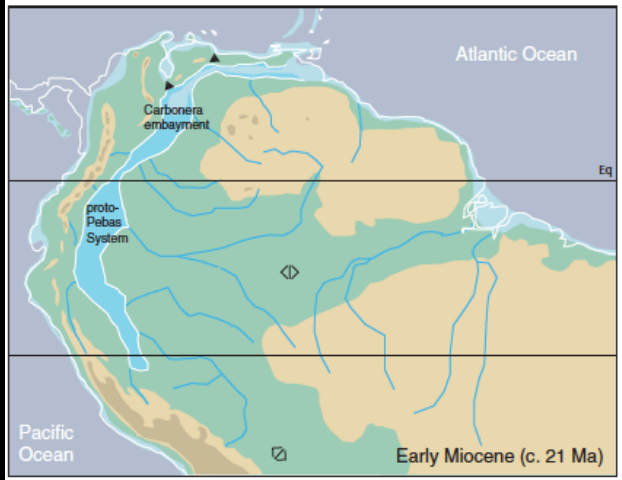
Diverse rainforest in western Amazonia
Diversification sub-Andean forests
Diverse aquatic and terrestrial megafaunas in western Amazonia
Extinction endemic invertebrate faunas western Amazonia



Middle Miocene (c. 11–16 Ma)

Continued uplift Central and Northern Andes
Pebas megawetland in western Amazonia
Modern monsoonal climate in Amazonia
Marine connections Amazonia-Llanos-East Venezuela Basin
Carbonate platforms along northern/ NE coasts South America
Major drainage divide in central-eastern Amazonia
Shield areas stable, deep weathering

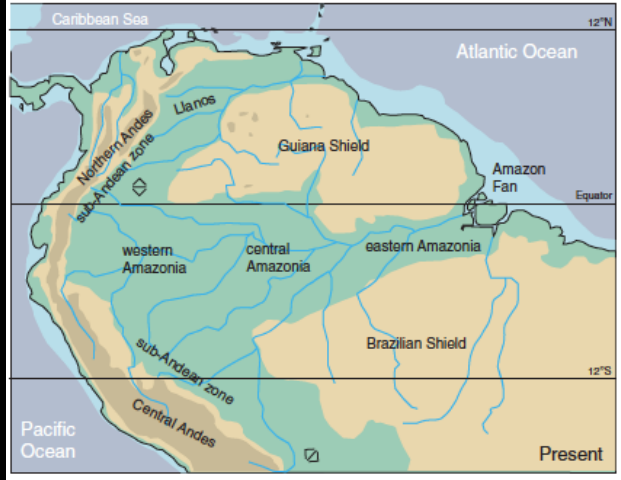
Diverse rainforest in northwestern Amazonia
Intermediate diverse rainforest and savannas Eastern Cordillera
Evolutionary radiations invertebrates in Pebas megawetland system
Very diverse terrestrial and aquatic vertebrate faunas western Amazonia



Early Miocene (c. 16–24 Ma)

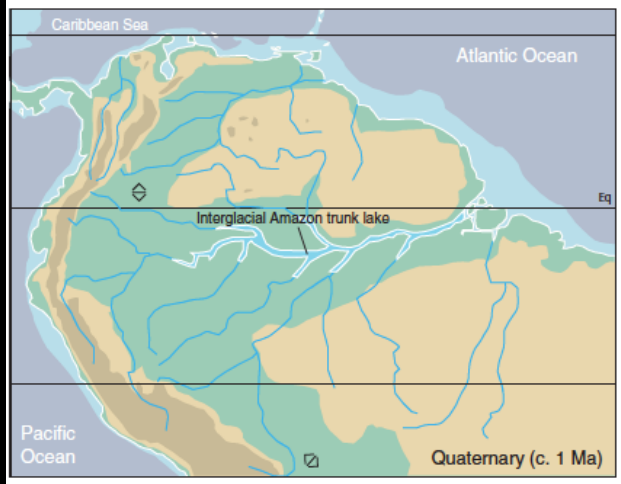
Uplift Central Andes
Localized uplift Eastern Cordillera (Northern Andes)
Drowning foreland basins
Onset Pebas wetland system
Modern monsoonal climate in Amazonia
Marine connections Amazonia-Llanos-East Venezuela Basin
Carbonate platforms along northern/NE coasts South America
Major drainage divide in central-eastern Amazonia
Shield areas stable, deep weathering

Intermediate diverse rainforest in northwestern Amazonia
Evolutionary radiations invertebrates in Pebas wetland system



LEGEND

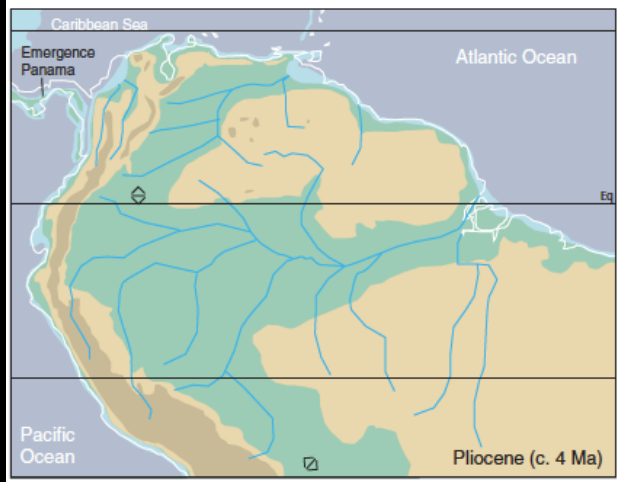
- Rivers
- Mountains (> 2000 m)
- Upland (200–2000 m)
- Lakes
- Lowland (0–200 m)
- Shallow marine (0– –1000 m)
- Ocean (< –1000 m)
- Major drainage divide
- Possible drainage corridor



Quaternary (<2.6 Ma)

Andean glaciations
Increased Andean denudation
Increased sedimentation Amazon submarin fan
Progradation Guyana coastal plain
Inion cycle in trunk Amazon River
Episodic aridification of Amazonian periphery

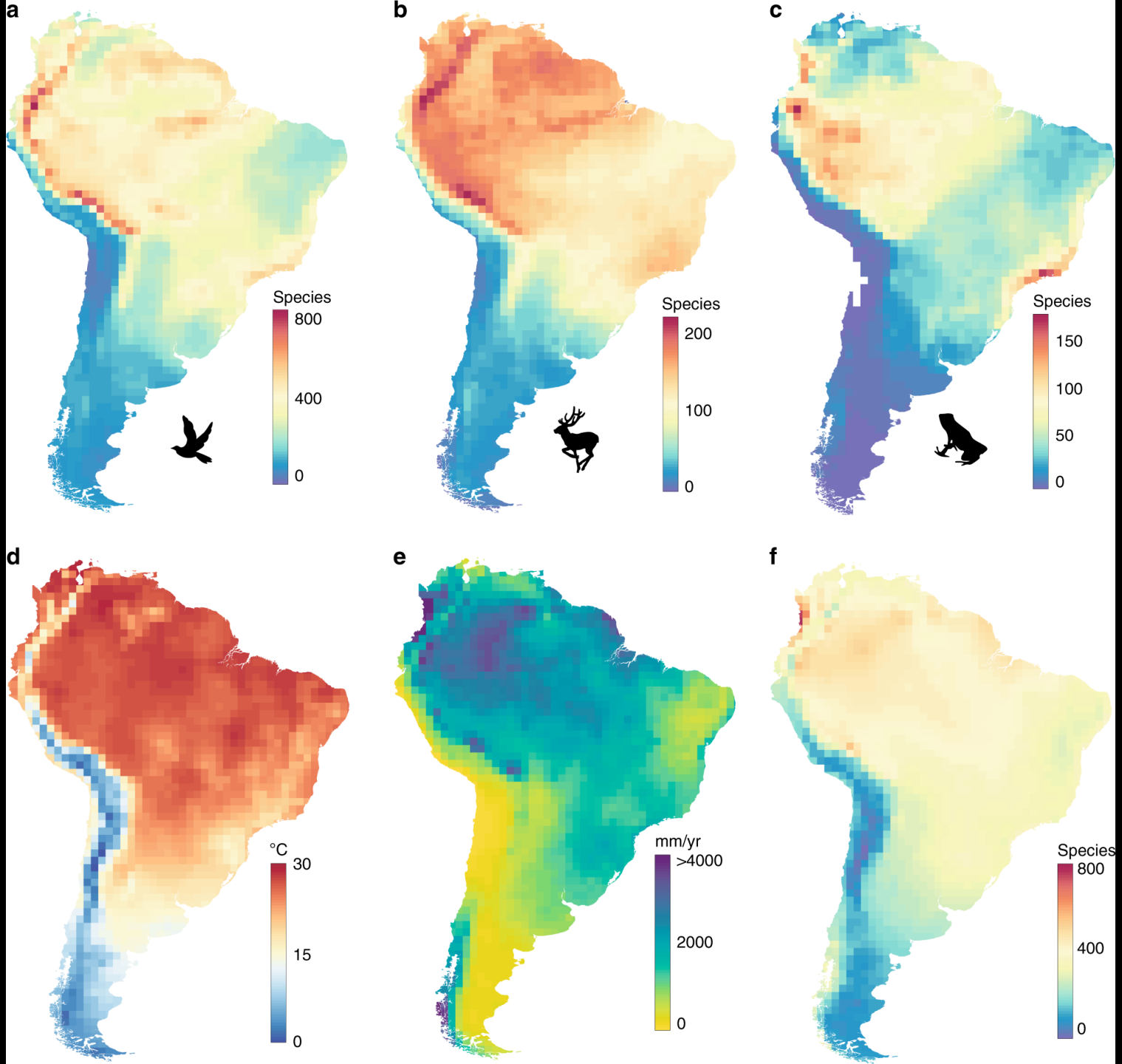
Permanent rainforest in central-western Amazonia
Compositional change rainforest
Diversification Páramo floras in northern Andes



Latest Miocene – Pliocene (c. 2.6–7 Ma)

Closure Panama land bridge (c. 3.5 Ma)
Strong concerted uplift entire Andes
Development of Amazon fluvial system
Increased sedimentation rates in Amazon submarine fan
Dynamic low relief river systems (including megafans) western Amazonia
Andean derived nutrients spread over eastern Amazonia
Progradation Guyana coastal plain
Aridification Venezuelan coastal area
Shield areas stable, deep weathering

Diverse rainforest in western Amazonia
Onset development Páramo vegetation
Onset GABI (Great American Biotic Interchange)
Onset extinction megabodied mammals
Disappearance Amazonian biota in northern Venezuela


a
Species
800
400
0
b
Species
200
100
0
c
Species
150
100
50
0
d
°C
30
15
0
e
mm/yr
>4000
2000
0
f
Species
800
400
0