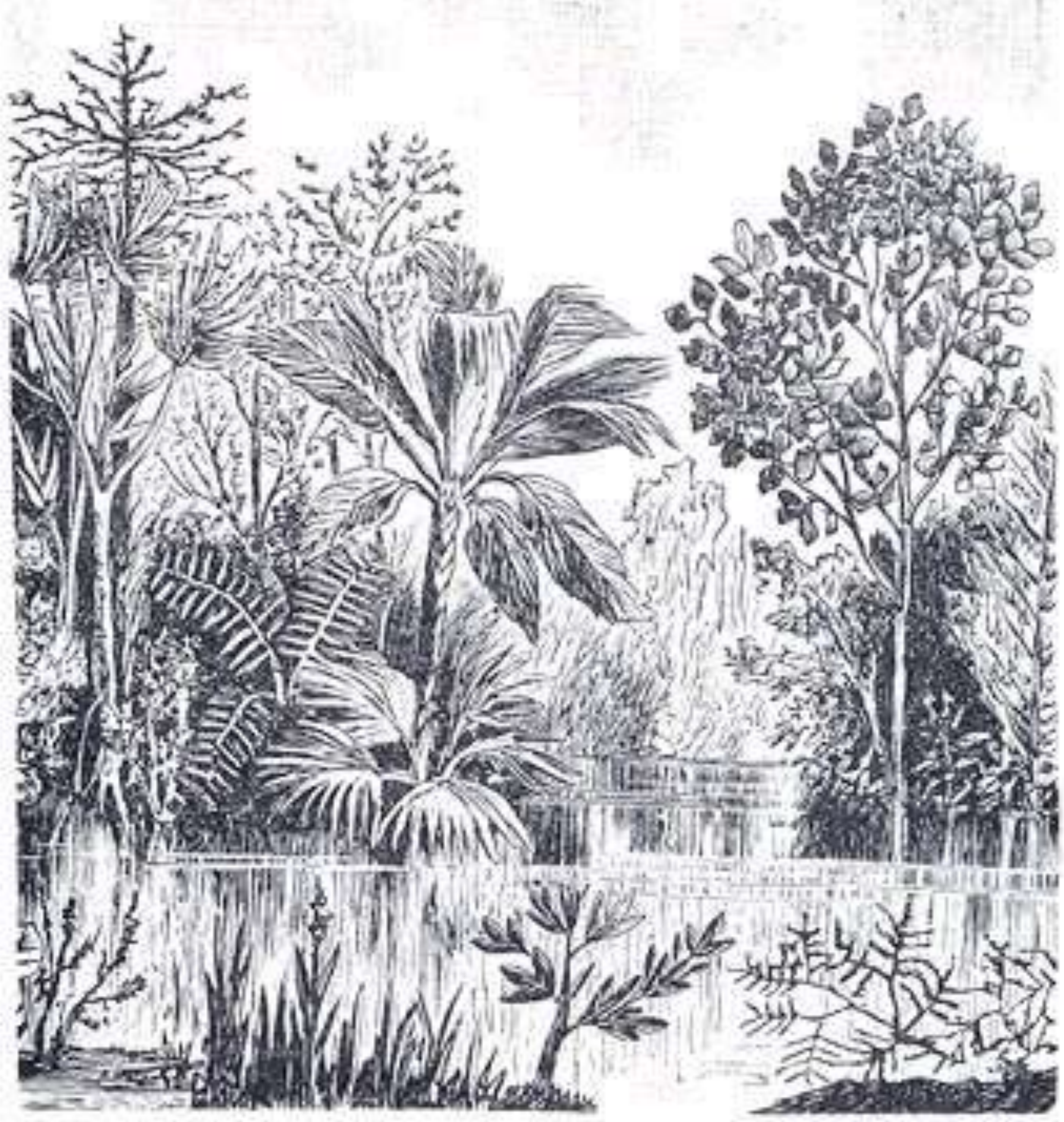
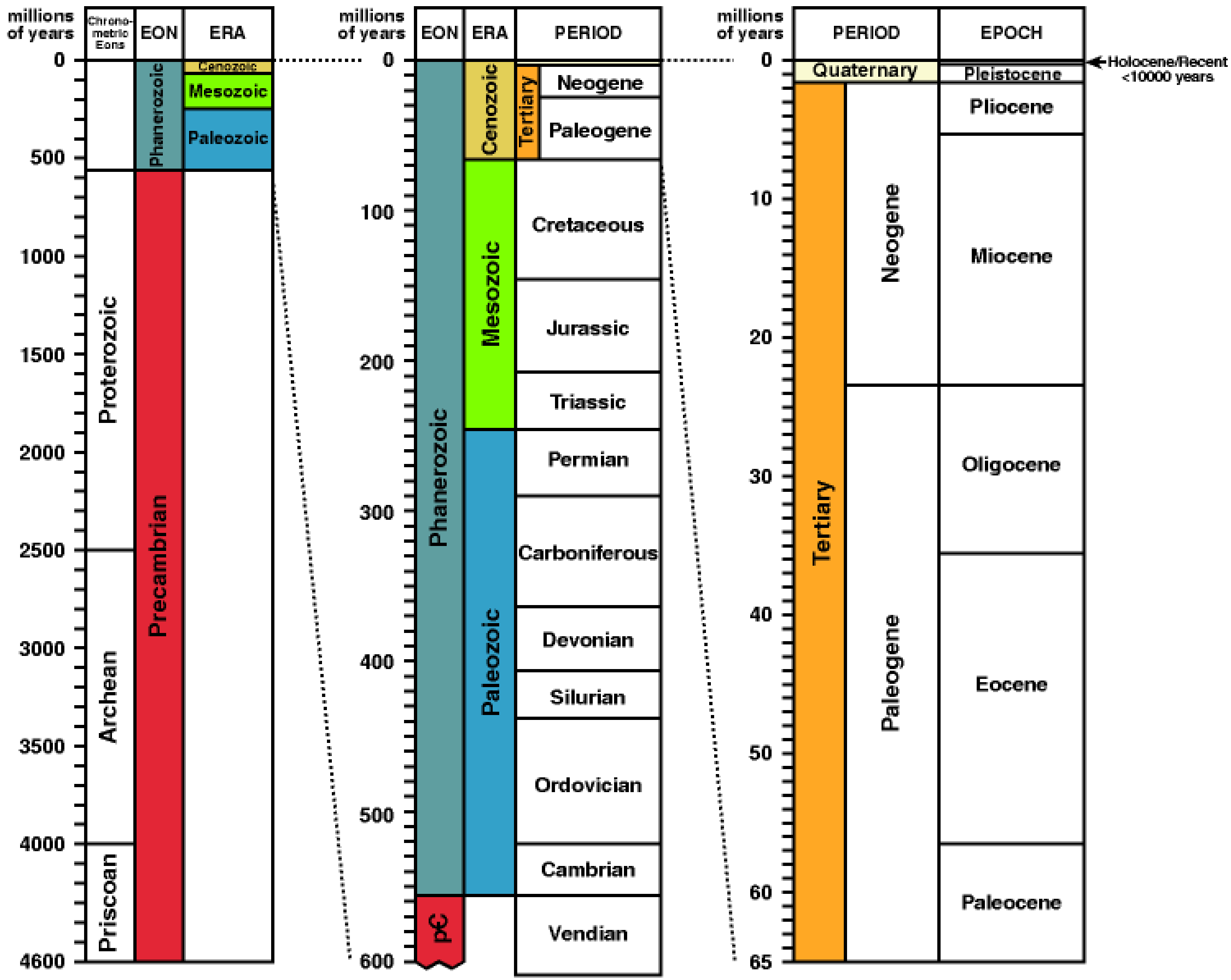
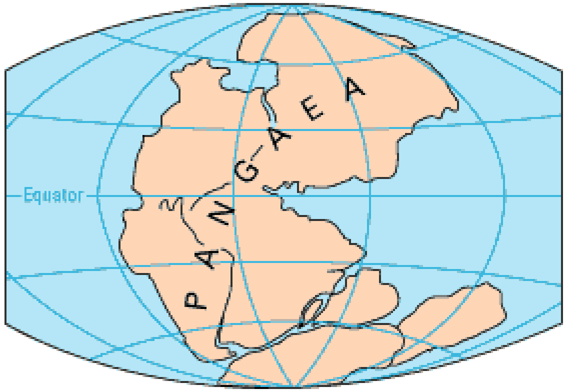
Evolutionary history of tropical forests



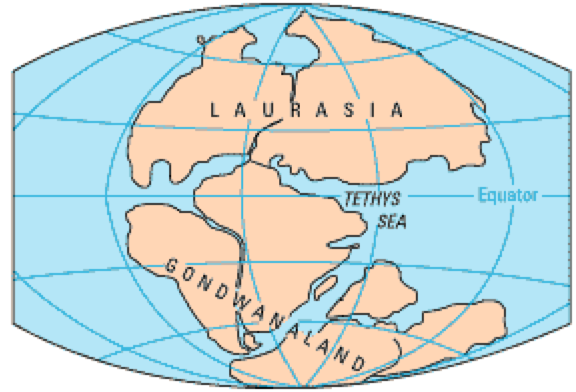
Nebraska forest of late Cretaceous times.

Geologic eras: a reminder of terminology...

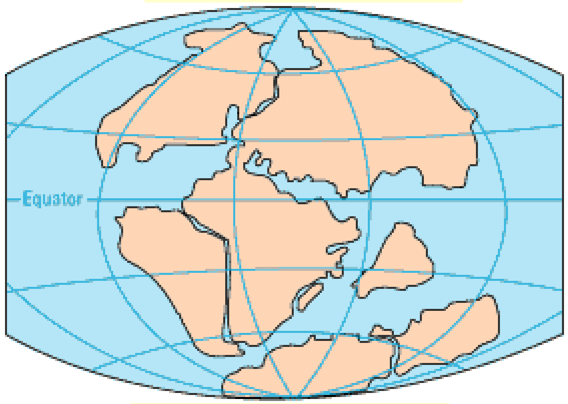




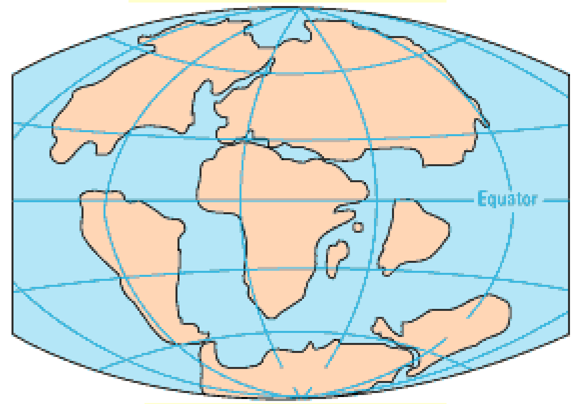
Permian
225 million years ago



Triassic
200 million years ago

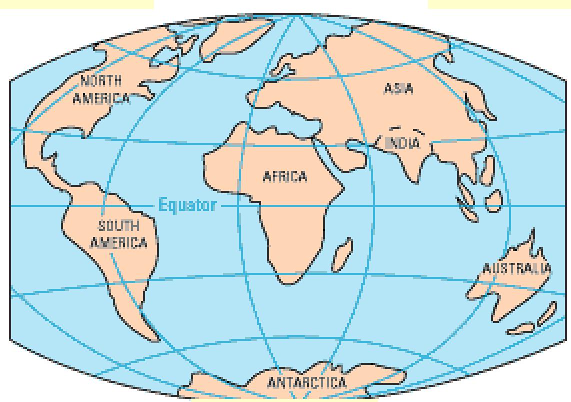


Jurassic
135 million years ago



Cretaceous
65 million years ago

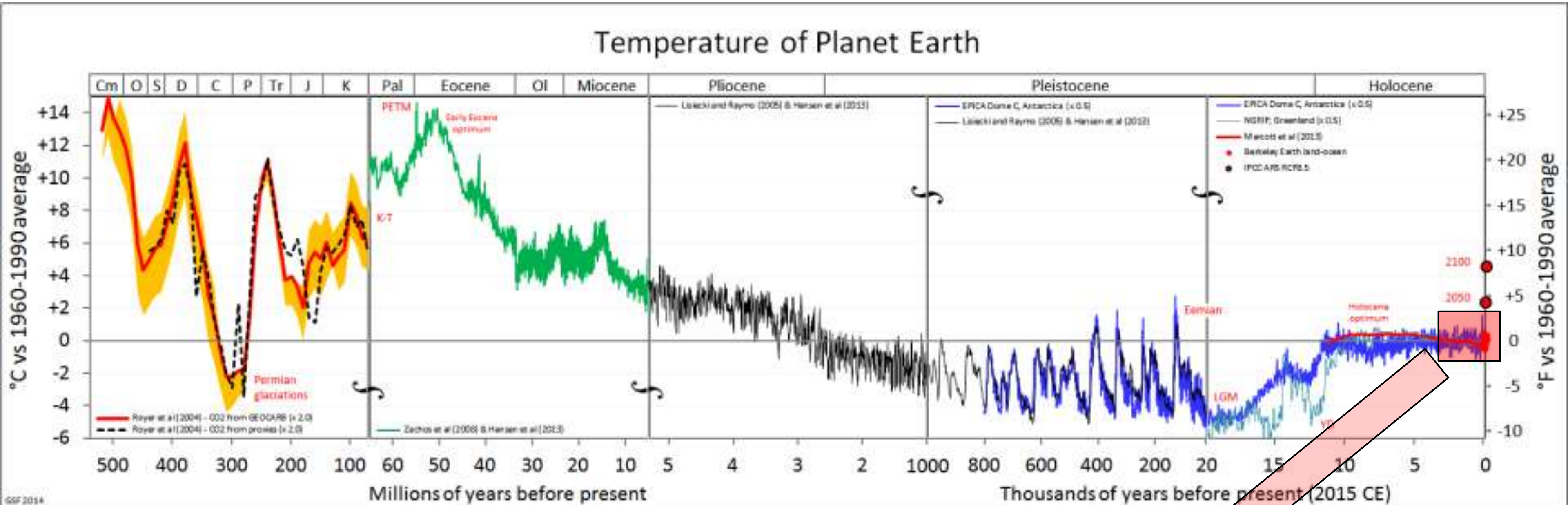
Politics of Pangea



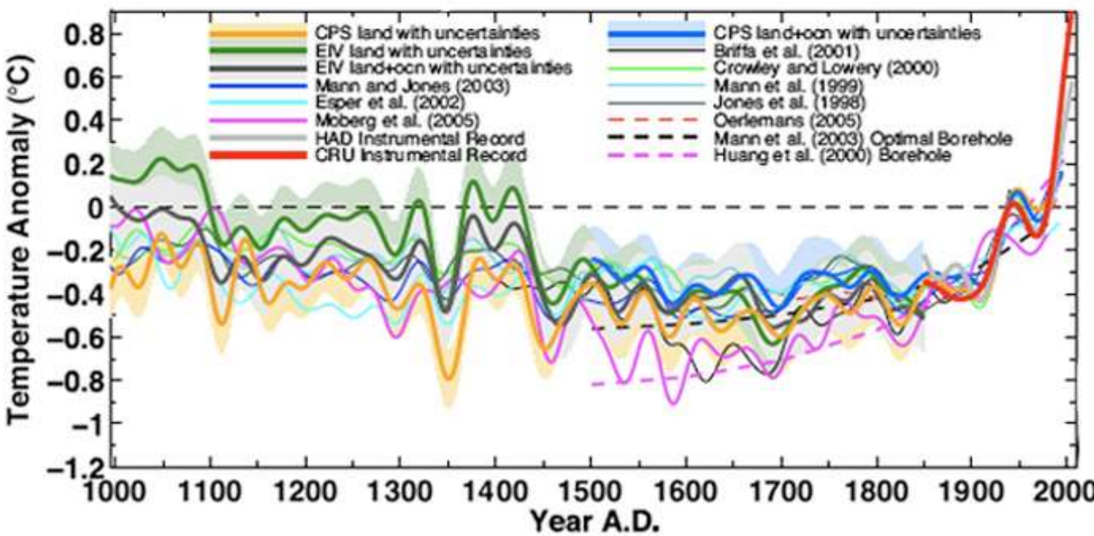
Present day

The Earth: always changing

Climate has been quite variable in the Earth's history

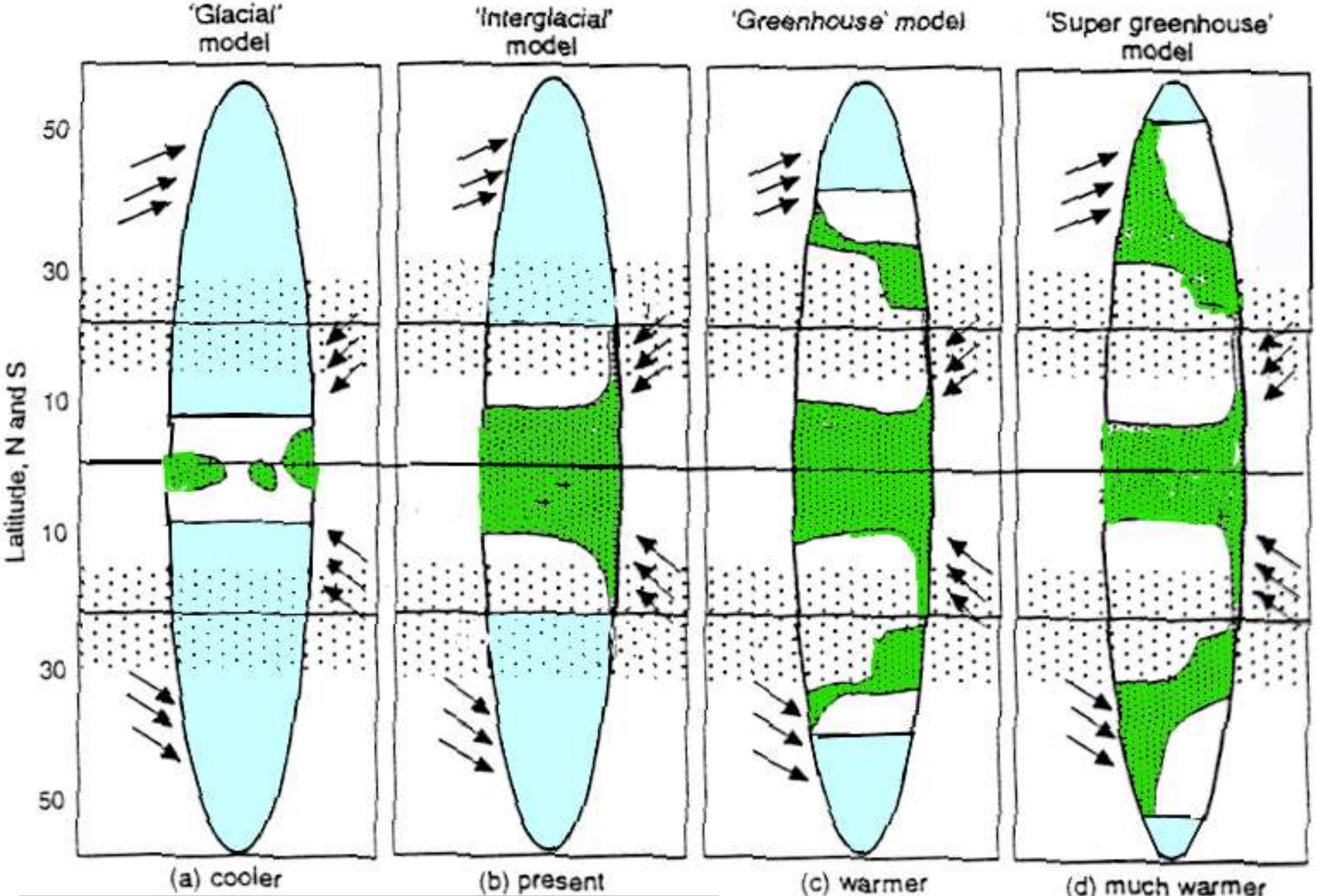


Note several separate time scales in this figure



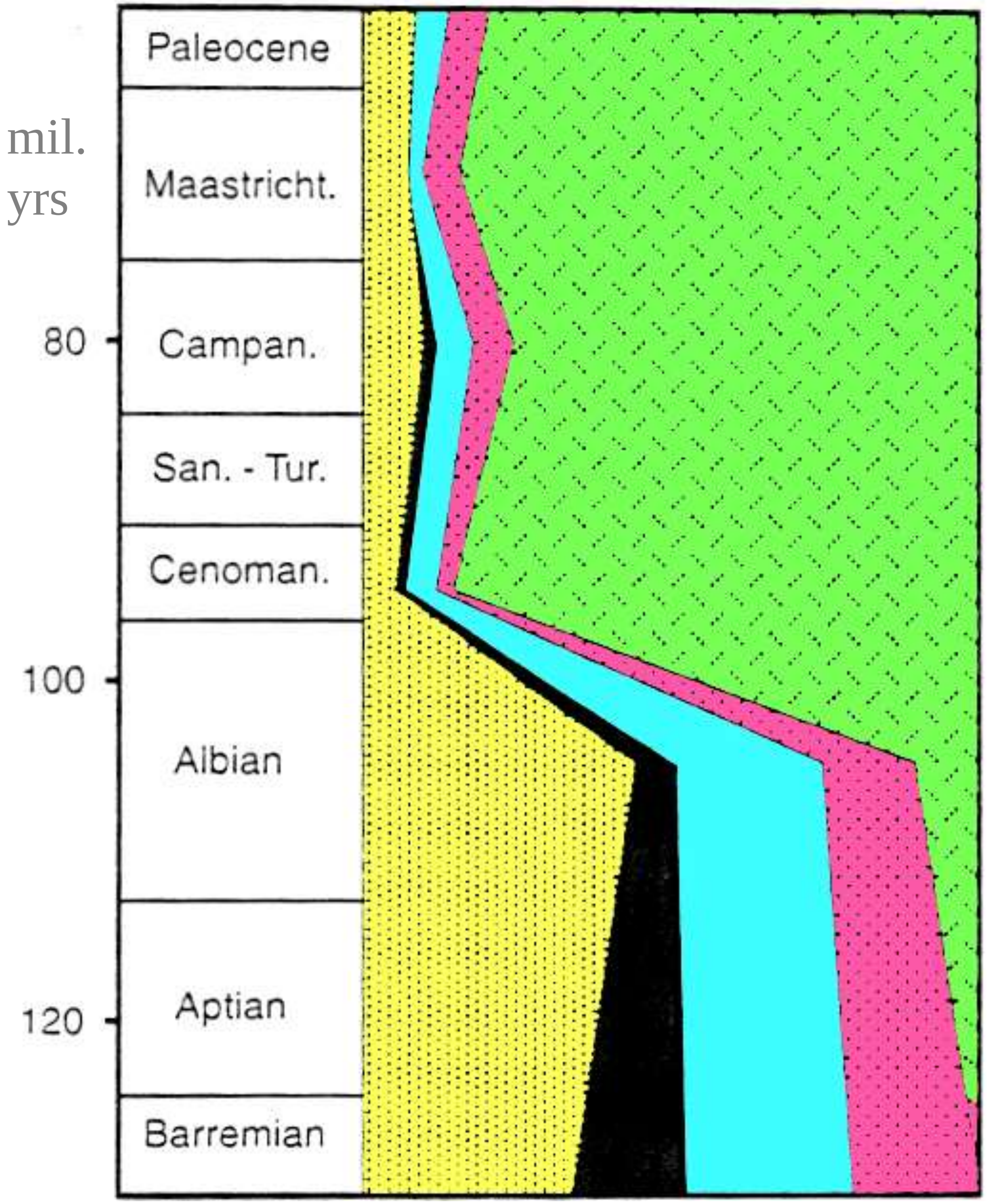
Our recent climate change looks rather small in the historical context of the last 500 million – or even only 20,000 – years…

Rainforest distribution under various climate regimes



RAINFOREST FROST LIMITS

Angiosperm revolution: 90 million years ago



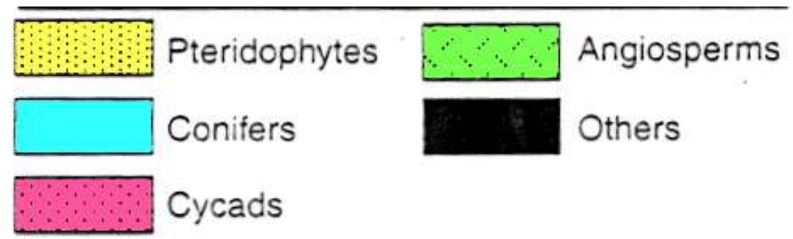
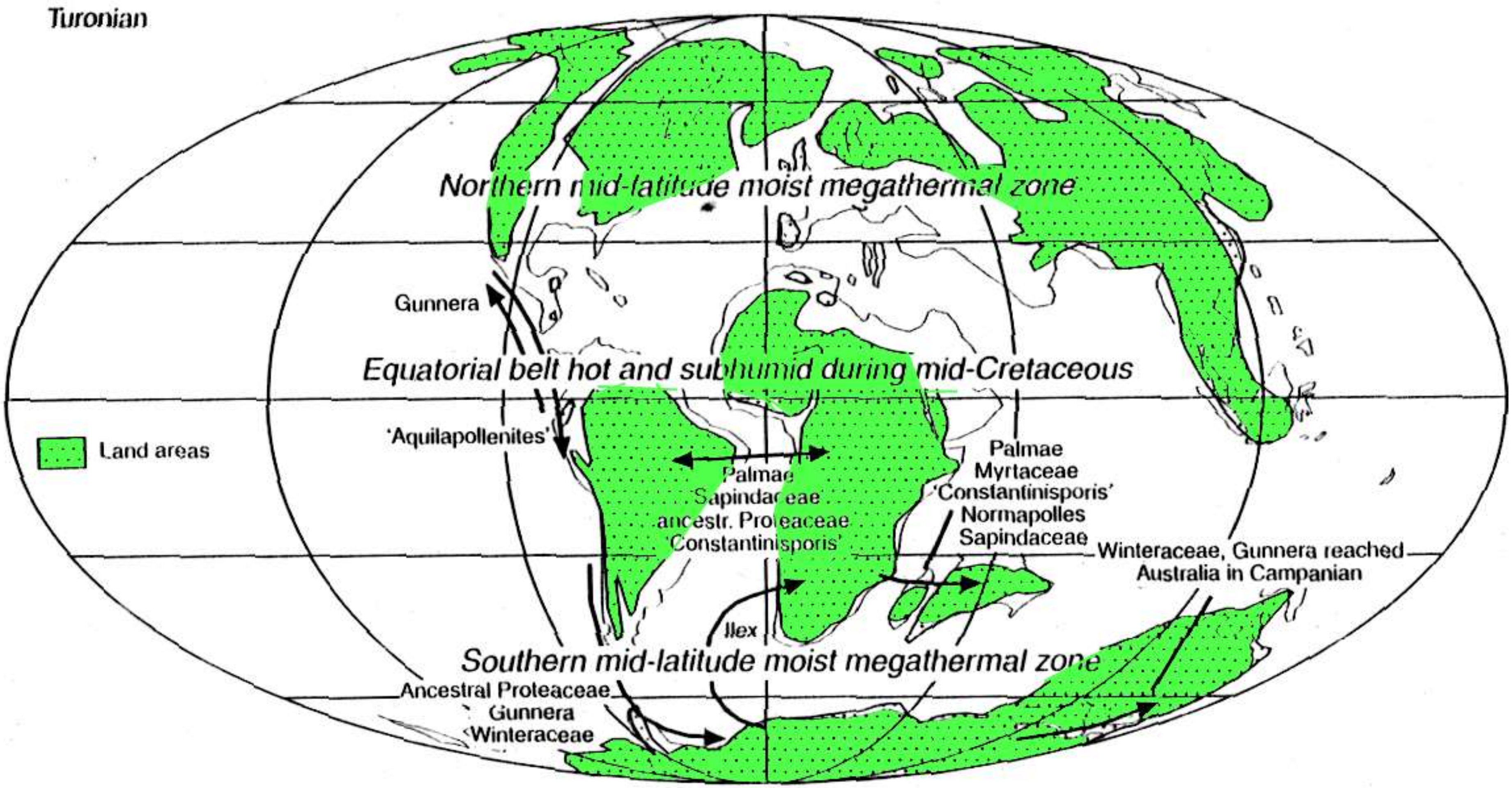


Figure 5.6 Changes in mean contribution of major plant groups to Jurassic, Cretaceous and Paleocene floras (after Crane, 1987). Scale in Ma. Reproduced by permission of Cambridge University Press.

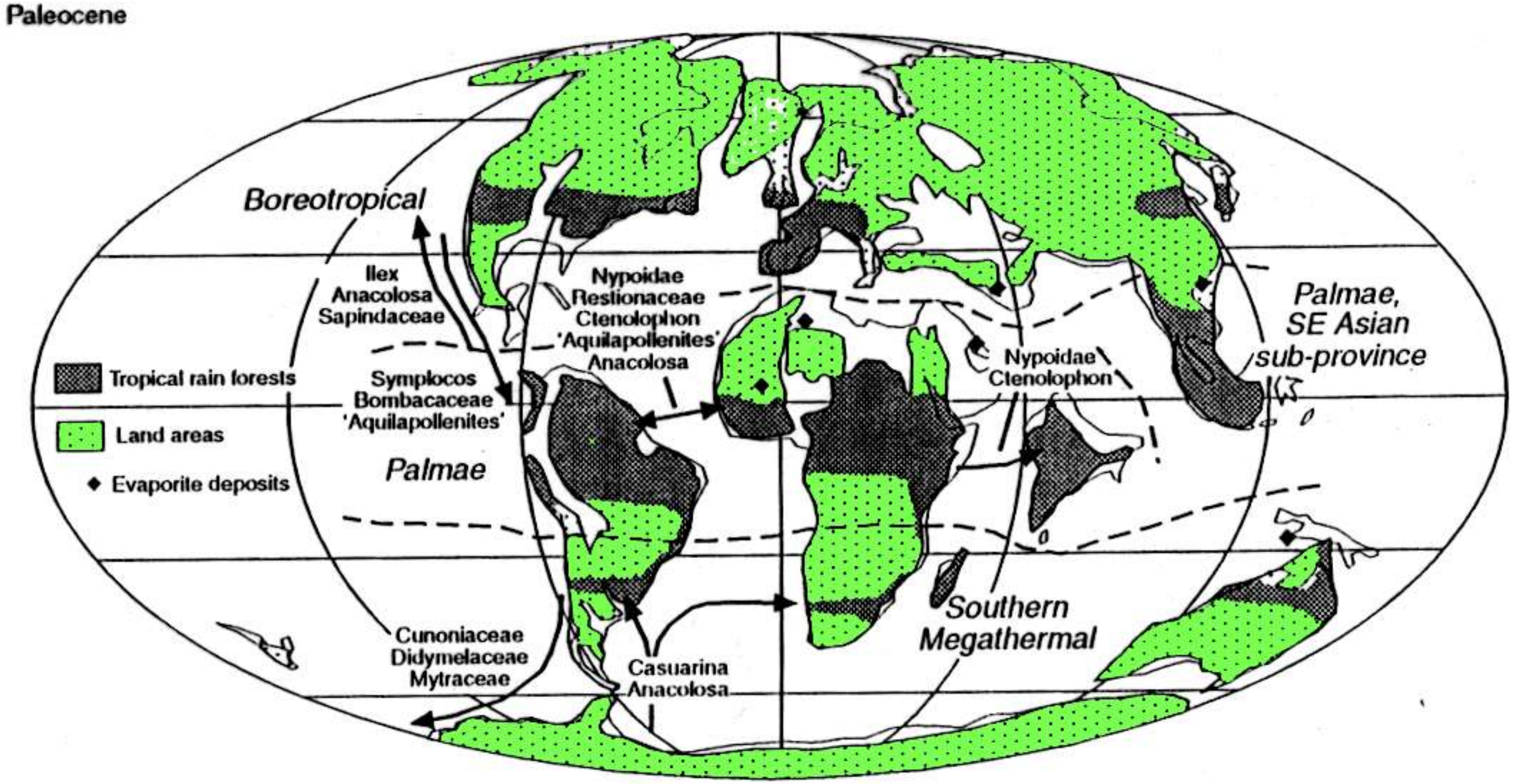
Late Cretaceous: origin of many rainforest plant taxa



Late Cretaceous - origin of many megathermal angiosperm taxa, ~ 90 ma

Figure 13.1 The three latitudinal belts within which moist megathermal angiosperm taxa first evolved. Turonian plate tectonic reconstruction with palaeogeography and coastlines according to Smith et al. (1994). Moist megathermal angiosperm-rich forests were widespread in northern and southern mid-latitudes during the earlier part of the Late Cretaceous, but did not develop in equatorial latitudes until the Campanian, prior to which time the equatorial climate was hot and subhumid. Noteworthy dispersals of megathermal taxa are indicated for the Turonian and Santonian/Coniacian, suggested by the palynological record.

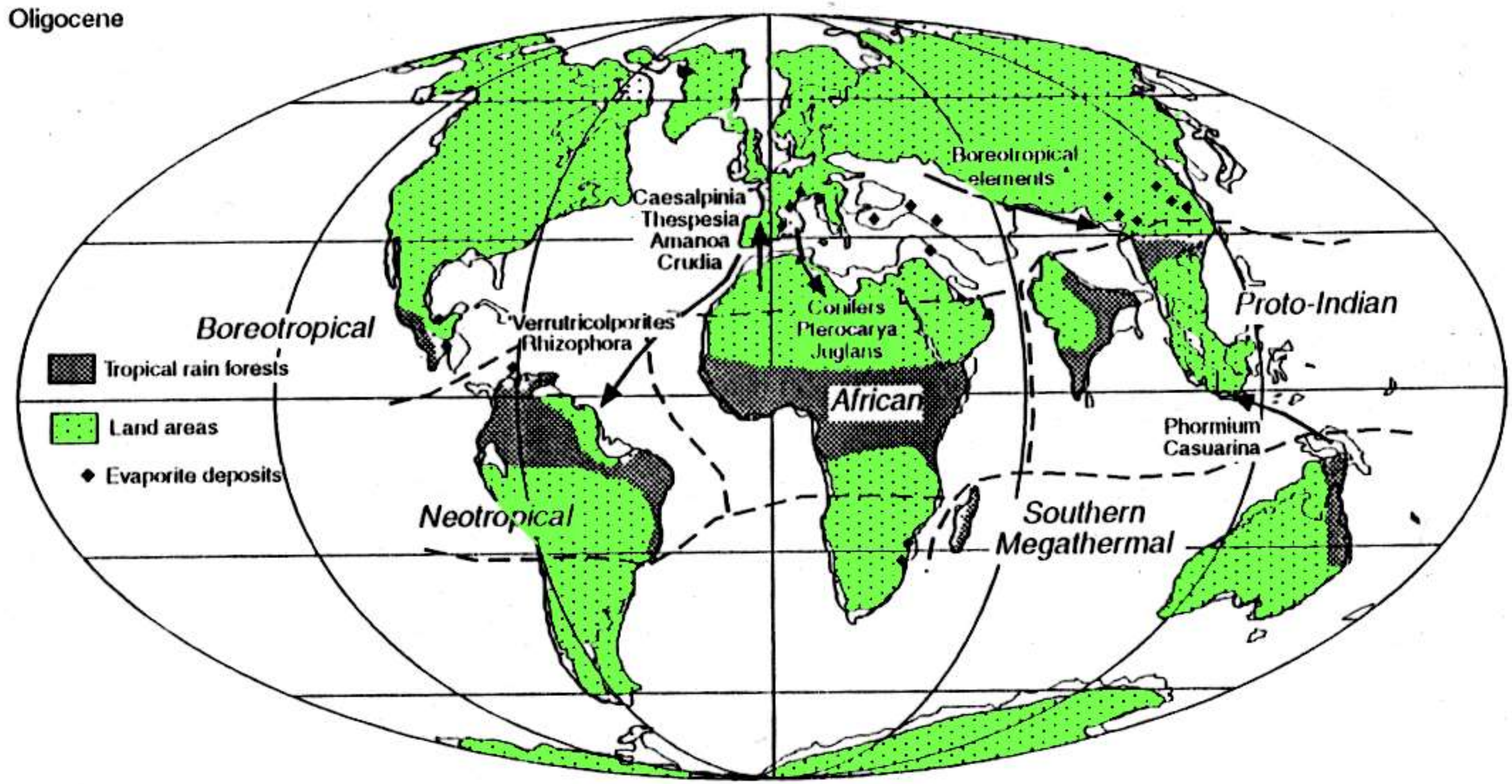
Paleocene: first closed canopy rainforests, in three tropical belts



Paleocene (60 ma) - first widespread closed canopy rainforest

Figure 13.2 Closed-canopy tropical rain forests first became widespread during the Paleocene. Reconstruction based on synthesis of Chapters 6–11, and, in the absence of positive evidence, to the 'greenhouse' climatic scenario presented in Figure 4.12c. Palaeogeography and palaeocoastlines from Smith et al. (1994); occurrences of evaporites from Parrish et al. (1982) with additions; megathermal floristic provinces as suggested in the text. Noteworthy Maastrichtian and earlier Paleocene dispersals of megathermal taxa (prior to the Late Paleocene/Early Eocene thermal maximum) are indicated, as suggested by the palynological record.

Oligocene: after Eocene cooling, rainforests only around the equator

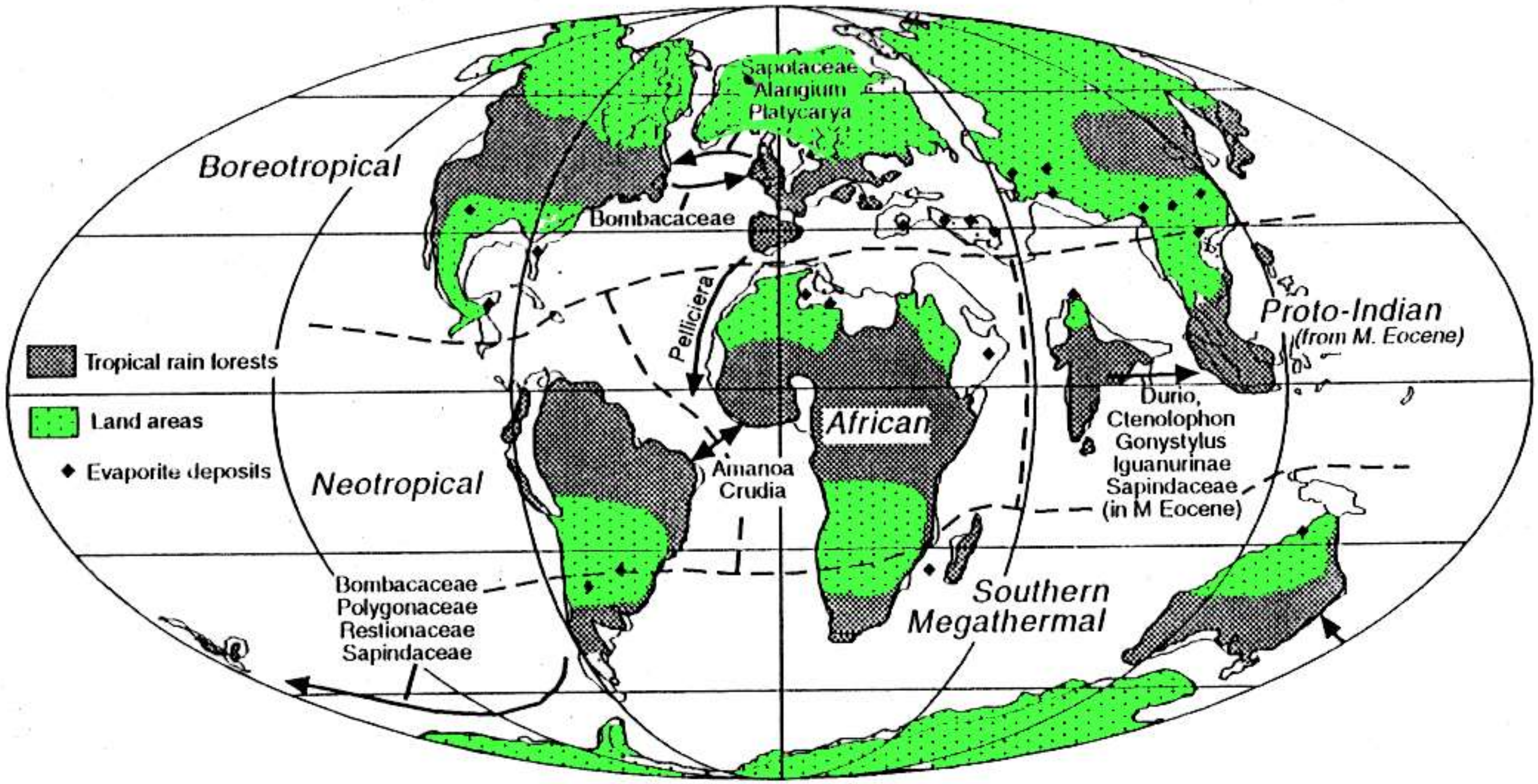


Oligocene (30 ma), after terminal Eocene cooling

Figure 13.4 Distribution of closed-canopy tropical rain forests during the Oligocene, following the terminal Eocene cooling event. Reconstruction based on synthesis of Chapters 6–11, and, in the absence of positive evidence, to the 'interglacial' climatic scenario presented in Figure 4.12b. Palaeogeography and palaeocoastlines from Smith et al. (1994); occurrences of evaporites from Parrish et al. (1982) with additions; megathermal floristic provinces according to the text. Noteworthy dispersals are indicated for (a) megathermal and microthermal plants which migrated at the time of the Late Eocene convergence of Europe and Africa; (b) boreotropical migrations (*conjectural) relating to the closure of the Turgai Straits; and (c) migrations of megathermal elements in relation to the latest Oligocene collision of the Australian Plate with SE Asia and the Philippine Plate.

Paleocene/Eocene thermal maximum: "super greenhouse" distribution of rainforests, resulting in many important dispersal events

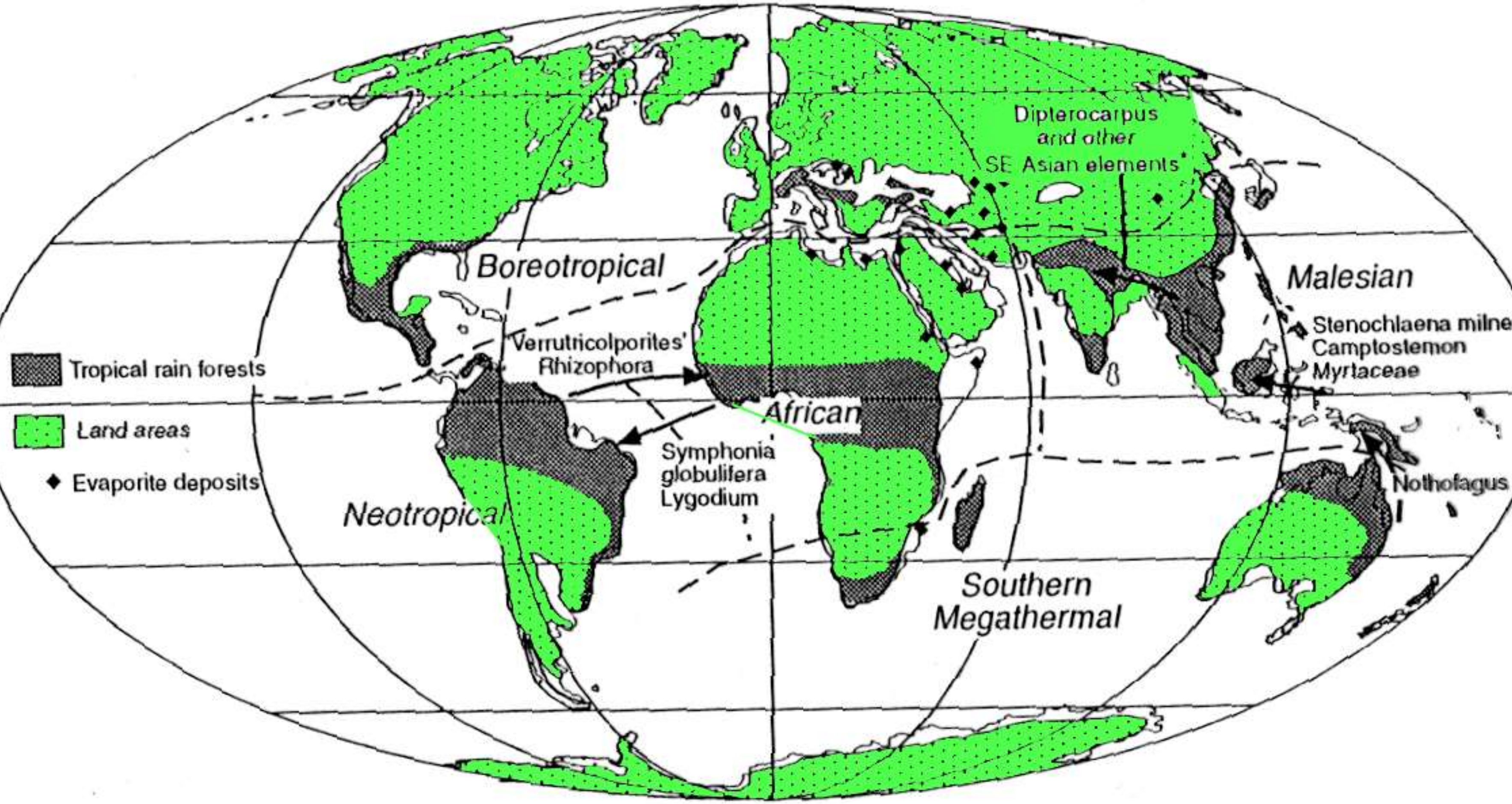
Ey Eocene



paleocene / eocene thermal maximum 55 ma

The sudden warming probably triggered by massive CO2 discharge from ocean see vents, or deep-ocean gas hydrates?

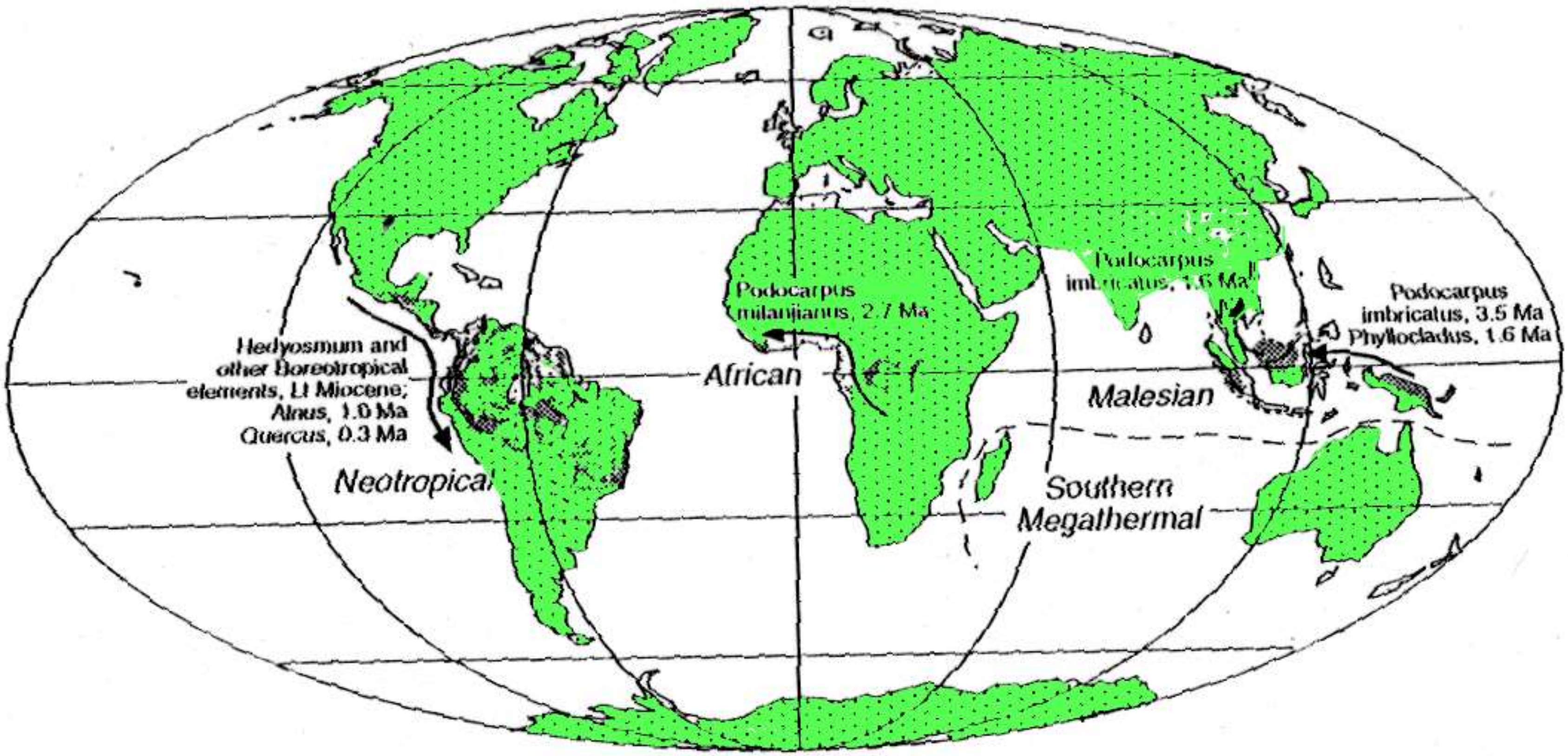
Miocene: “greenhouse” distribution of rainforests in a single wide belt



Miocene thermal maximum 15 ma

Figure 13.5 Distribution of closed-canopy tropical rain forests during the Middle Miocene, coinciding with the Miocene thermal maximum. Reconstruction based on synthesis of Chapters 6–11, and in the absence of positive evidence, to the ‘greenhouse’ climatic scenario presented in Figure 4.12c. Palaeogeography and palaeocoastlines from Smith et al. (1994); occurrences of evaporites from Parrish et al. (1982) with additions; megathermal floristic provinces according to the text. Noteworthy Miocene dispersals of megathermal plant taxa marked (*) are based on macrofossil data, otherwise based on the palynological record.

Last glacial maximum 16-20,000 yr ago: rainforests fragmented



last glacial maximum

Figure 13.6 Distribution of closed-canopy *tropical* rain forests during the last glacial maximum, based on the synthesis of Chapters 6–11. Contour lines in South America are postulated 1500 mm and 2000 mm isoyets for the last glacial maximum (Bush, 1994). Also shown are noteworthy instances of *Pliocene* and Pleistocene dispersals of *microthermal* taxa into the low latitudes.

Latitudinal extent of tropical rainforest climates is highly variable

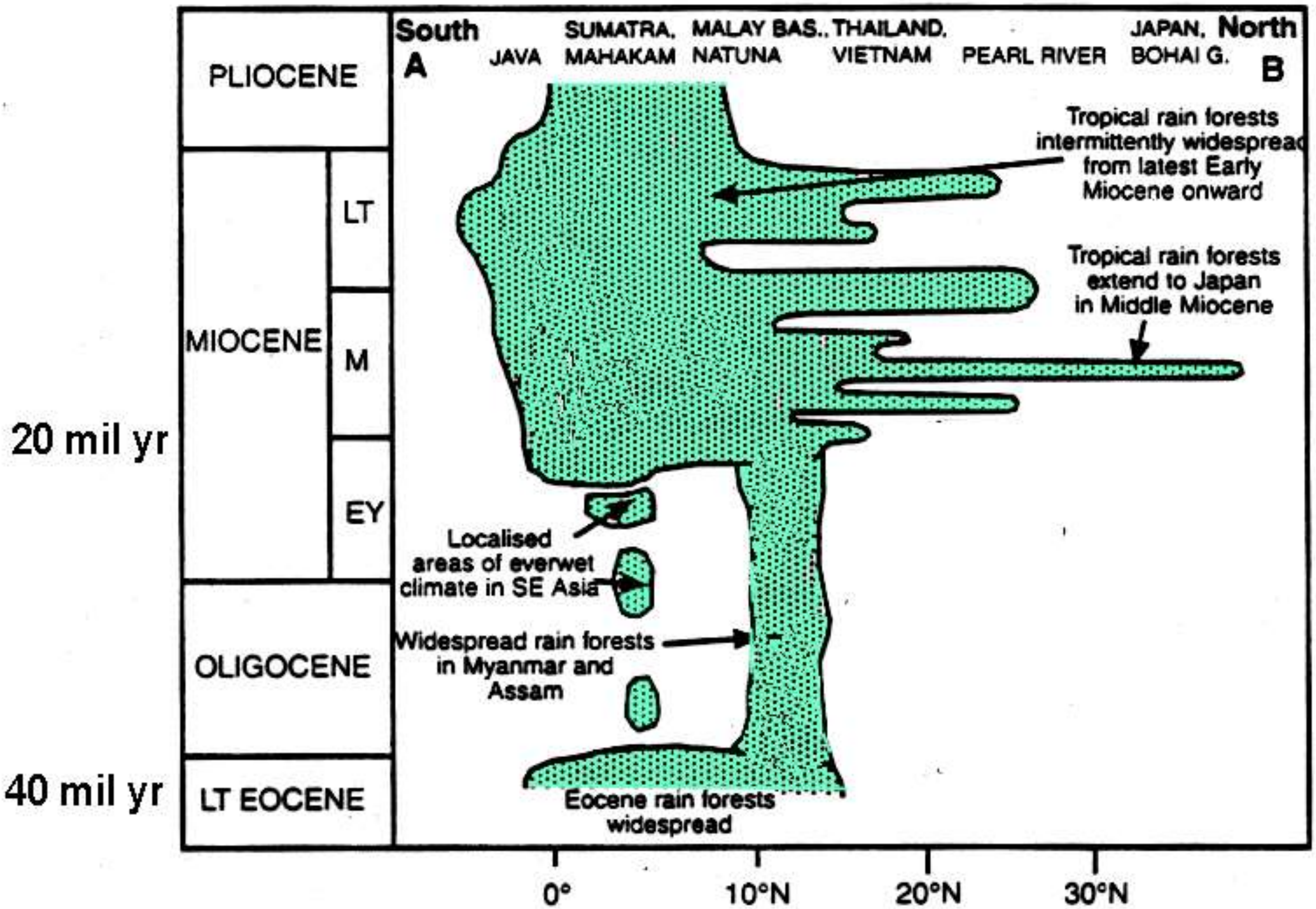
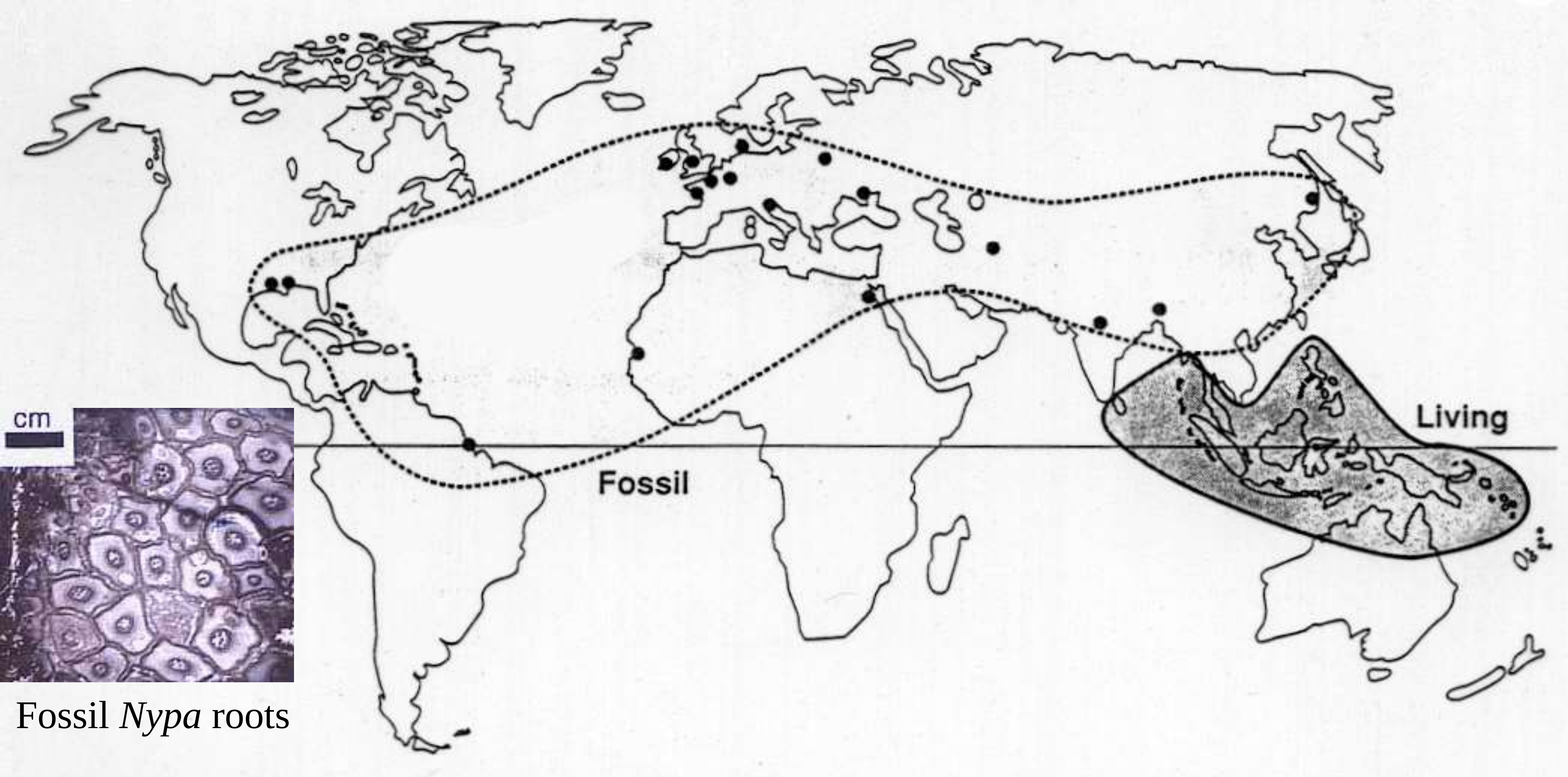


Figure 9.14 Schematic and simplified distribution of tropical rain forest climates in SE Asia during the Tertiary. Note that Eocene climates were moist, whereas in the Sunda region Oligocene climates were dry or seasonal, and opportunities for tropical rain forests were limited, possibly to localised areas with orographic rainfall. Rain forest climates did occur during the Oligocene in Assam and Myanmar. The greatest northward extension of rain forests occurred in the earliest Middle Miocene. Position of palaeoequator according to

Changes in distribution patterns: *Nypa fructicans*, one of the oldest contemporary palm species known from fossil records (70 mil years old)



Fossil *Nypa* roots

Figure 20.3 Fossil (symbols with dashed line) and contemporary (continuous line) distributions of the mangrove palm *Nypa*. (After Croizat 1968.)

Land bridge between the Americas: 3 million years ago

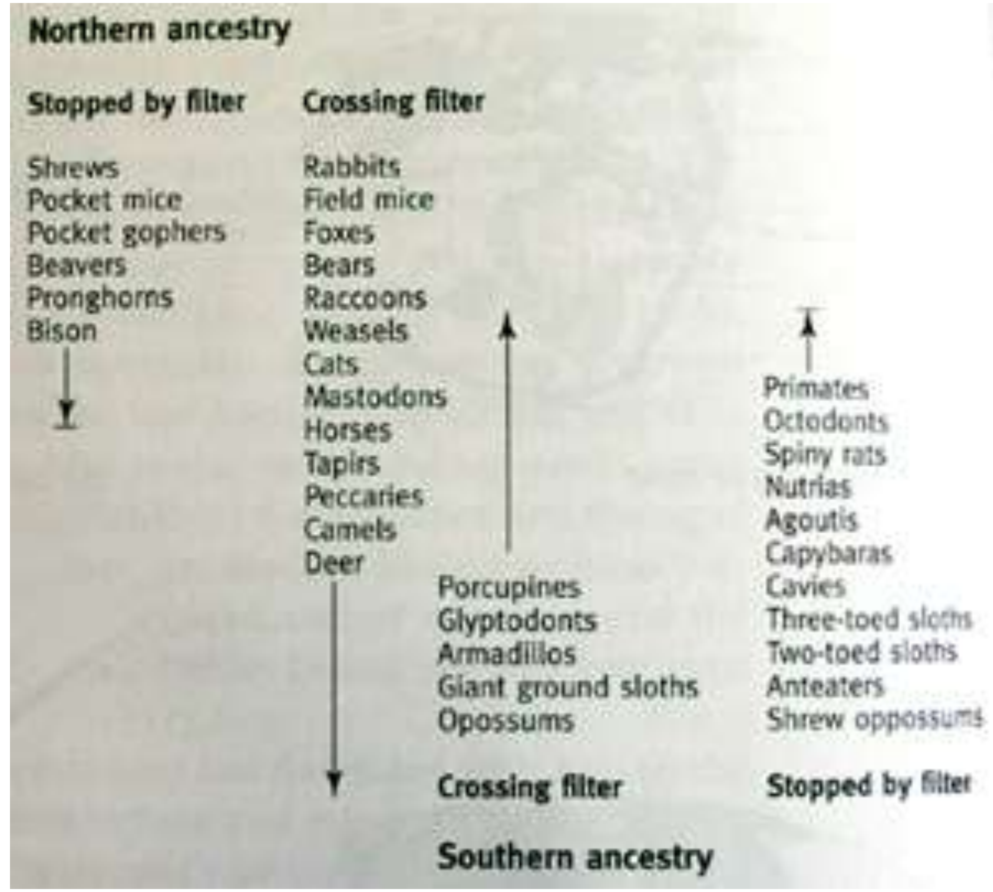
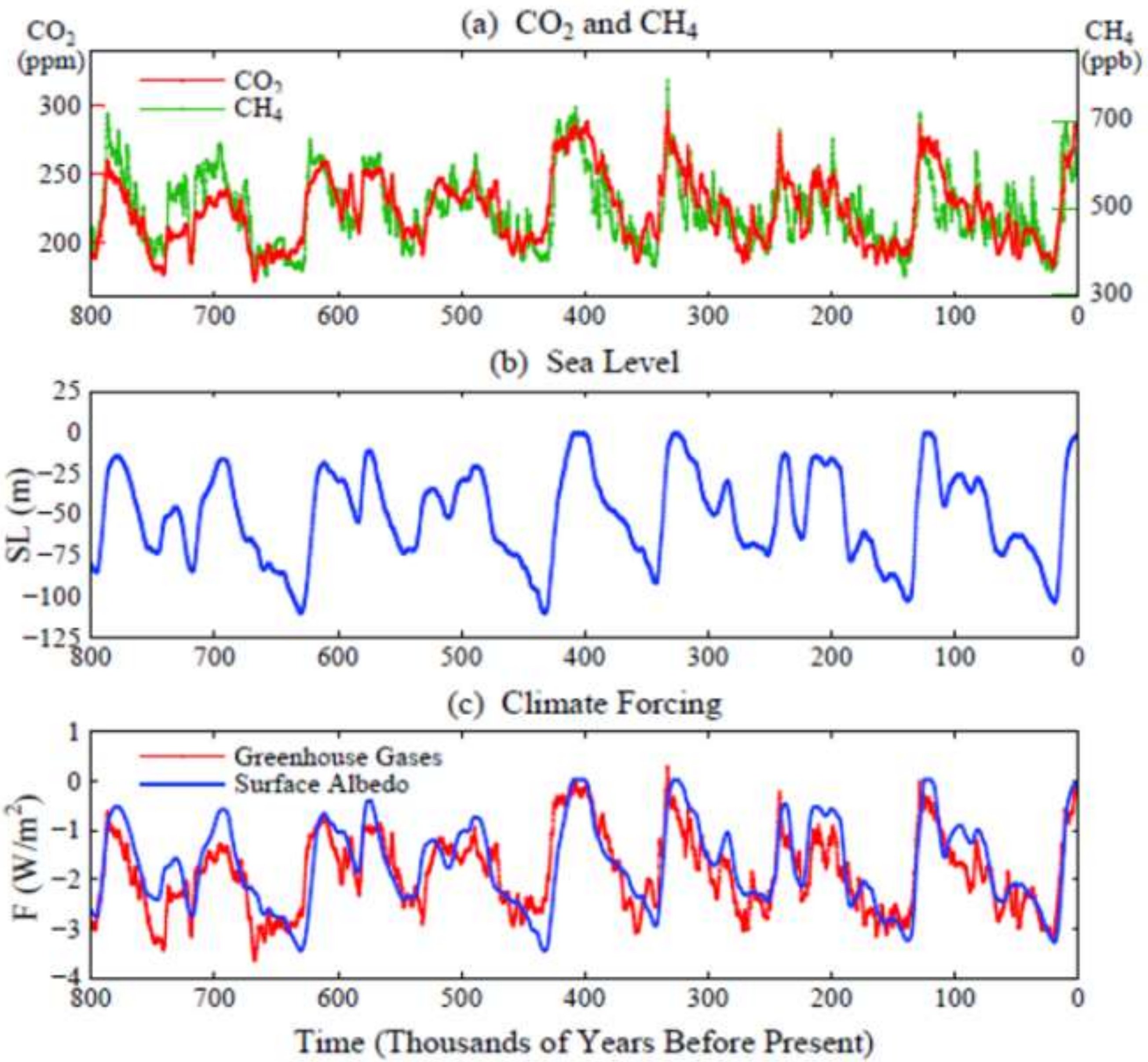
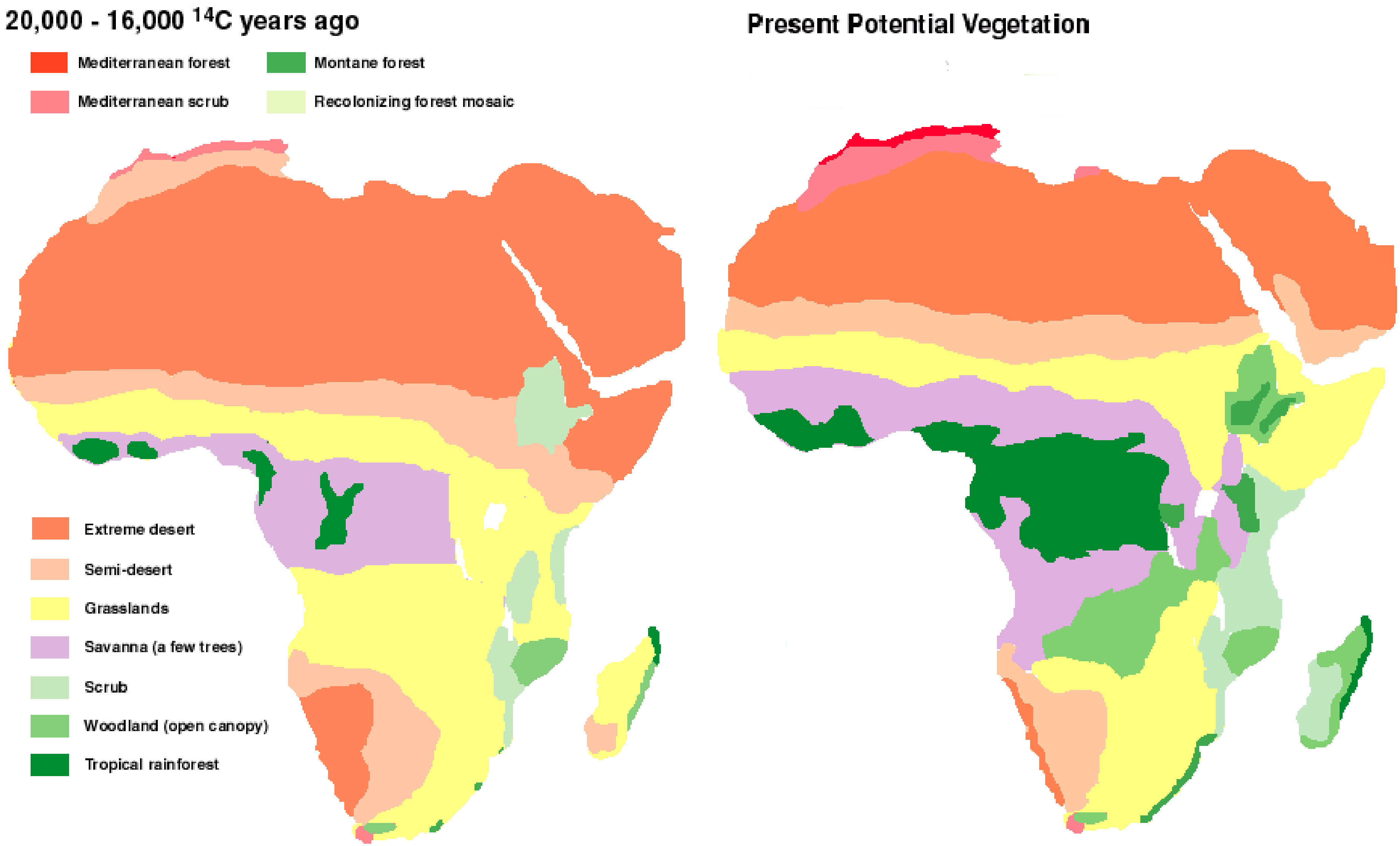


Fig. 1.8 The Central American land bridge, which was formed 3 million years ago, acted as a filter, preventing some North American animal families from crossing the barrier and allowing many others to pass on to South America. In contrast, many South American families did not disperse to North America. (From Brown & Lomolino 1998.)

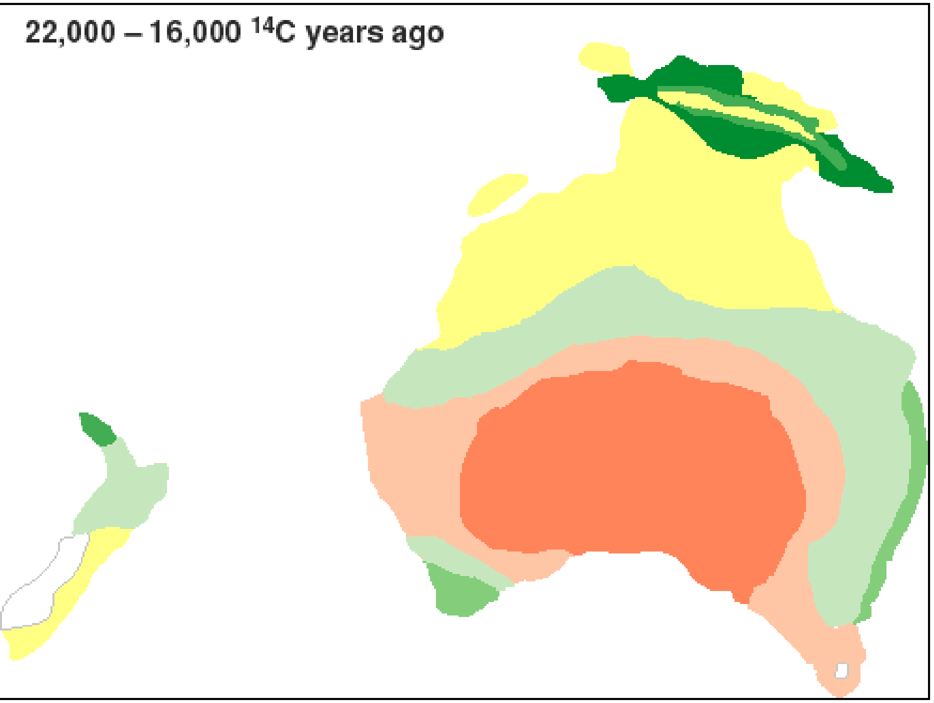
Our unstable times:
geologically fast changes in temperature and see level

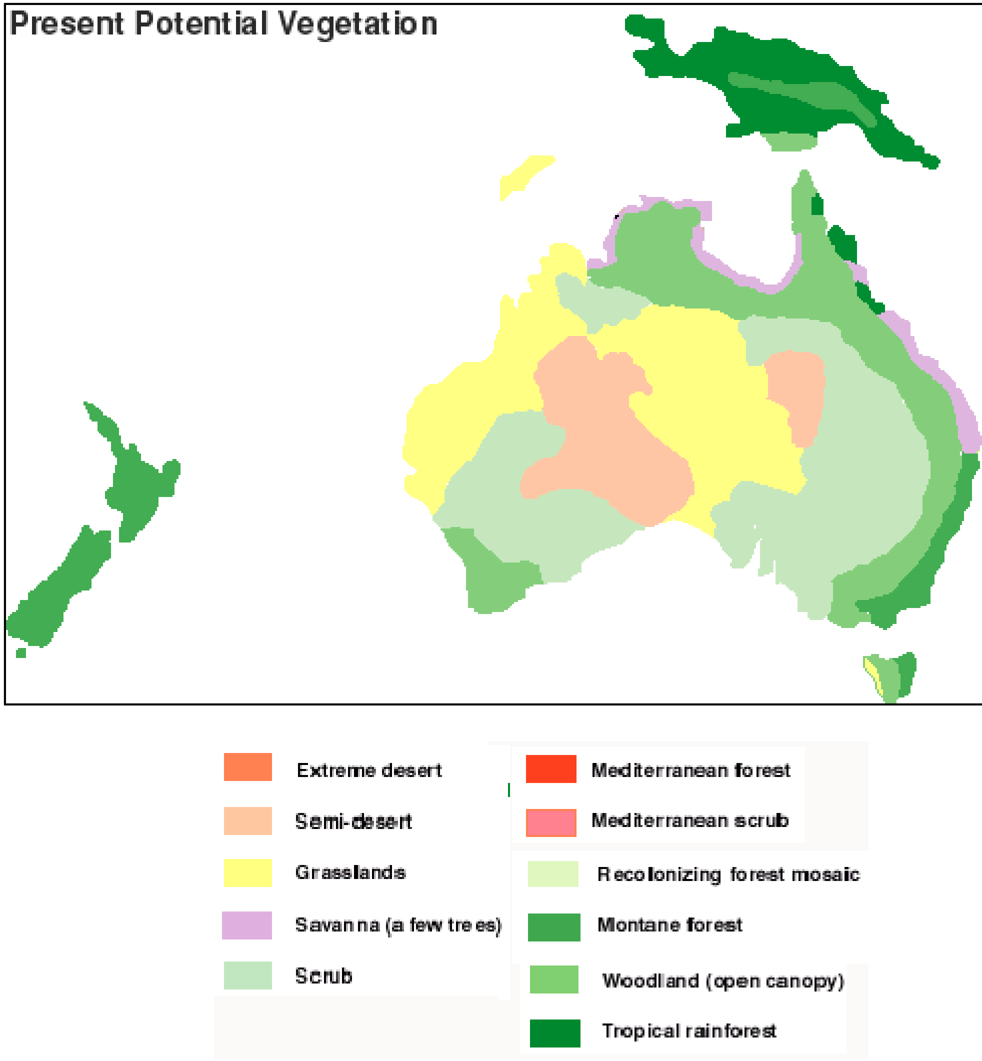


Vegetation change between last glacial maximum and present



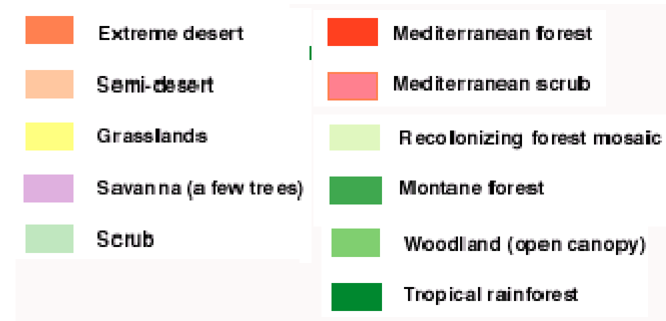
Vegetation change between last glacial maximum and present

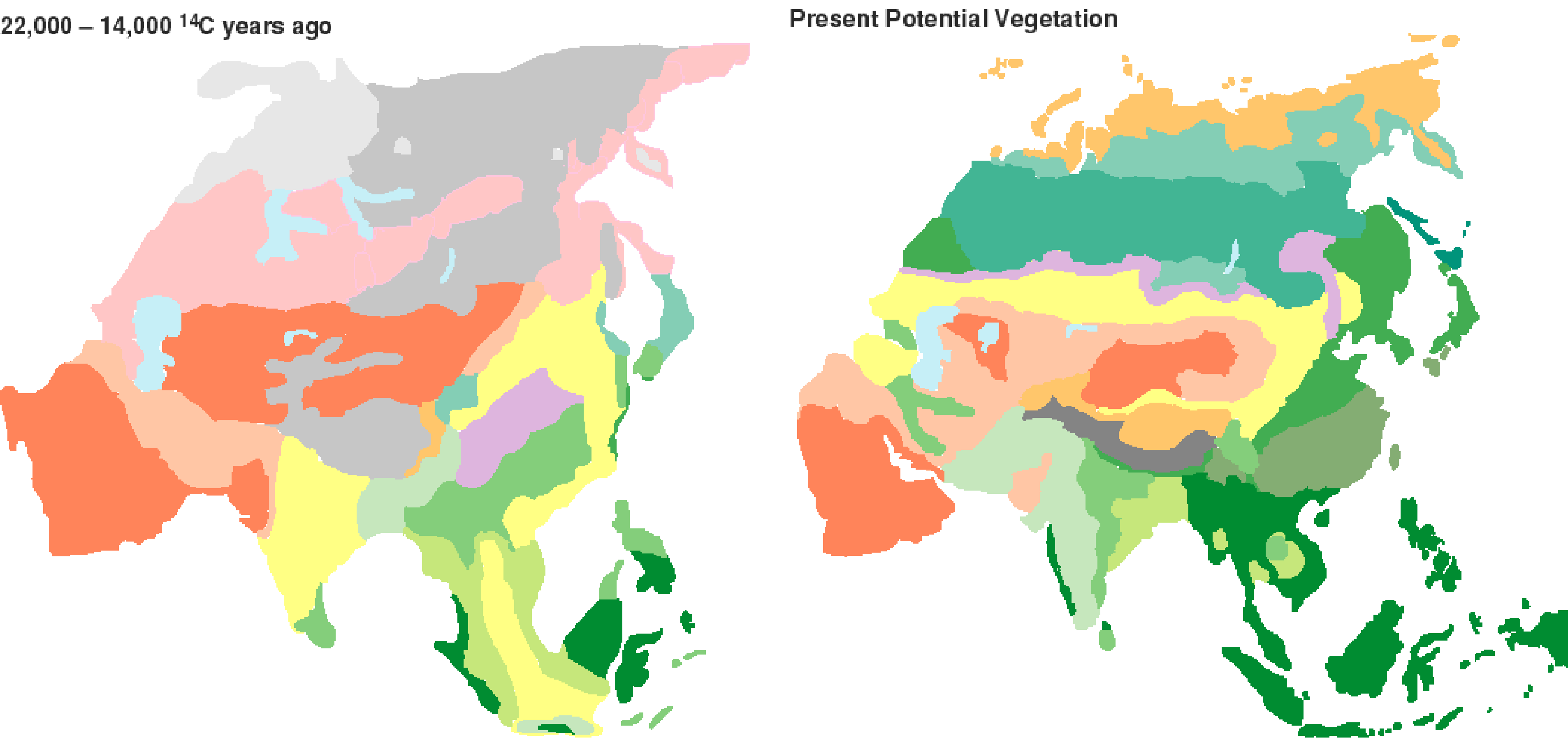




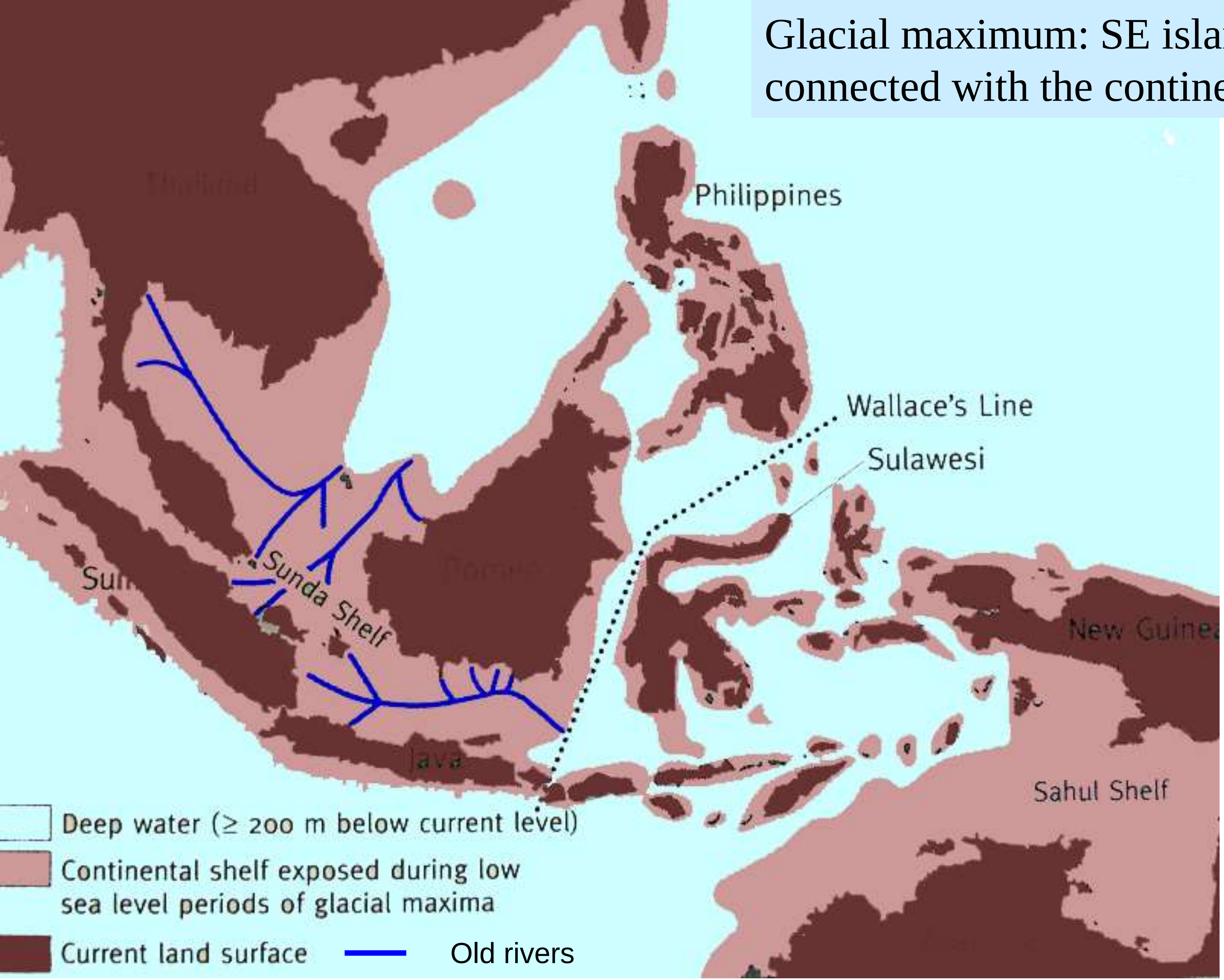
22-16 ya - glacial maximum

Vegetation change between last glacial maximum and present





Glacial maximum: SE islands connected with the continent



Changes in altitudinal zonation from the last glacial maximum

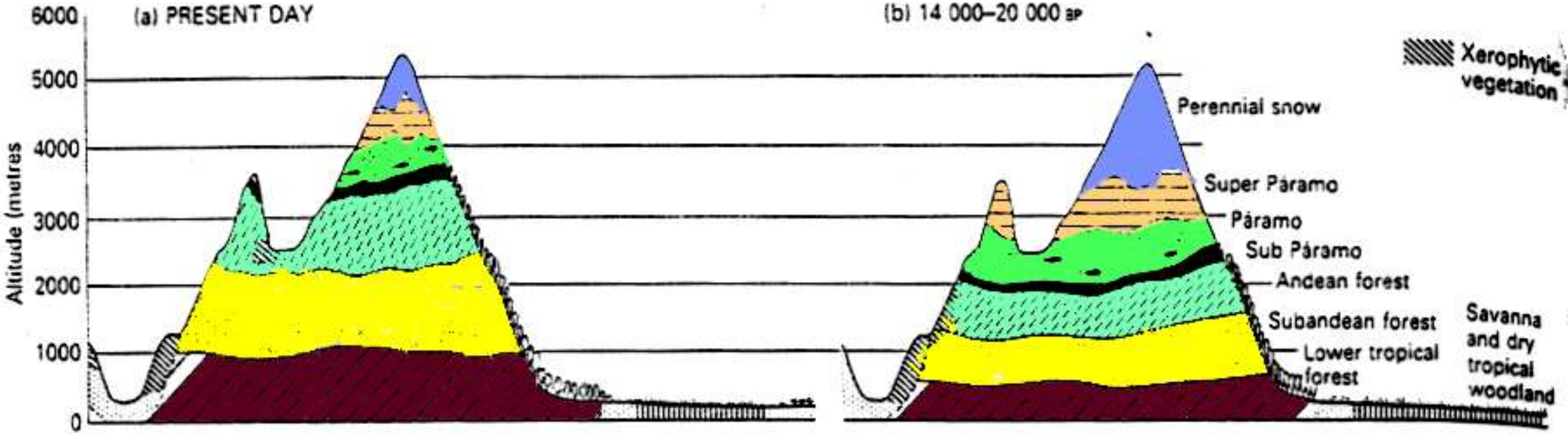
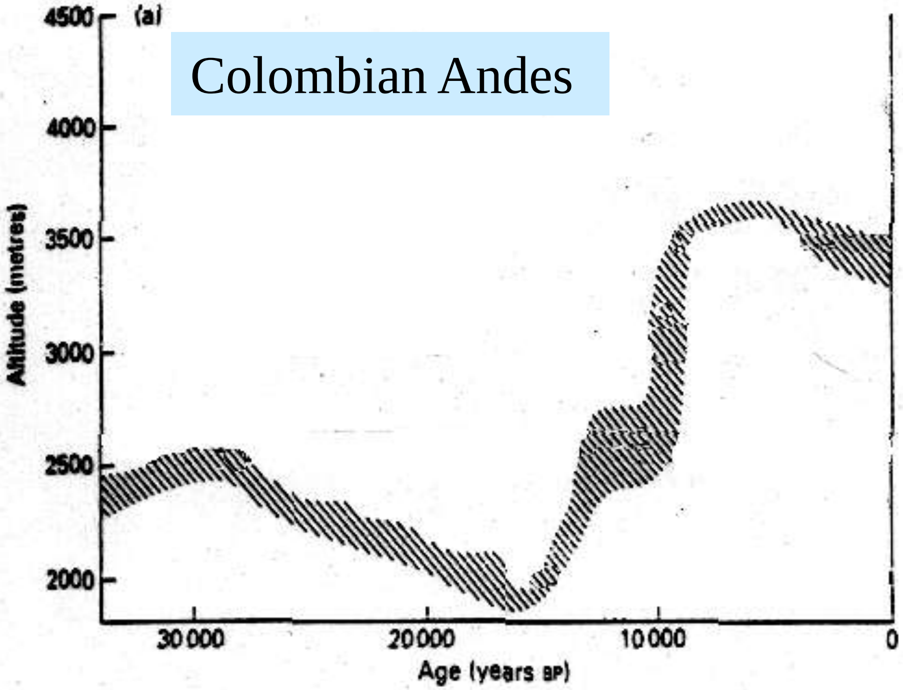
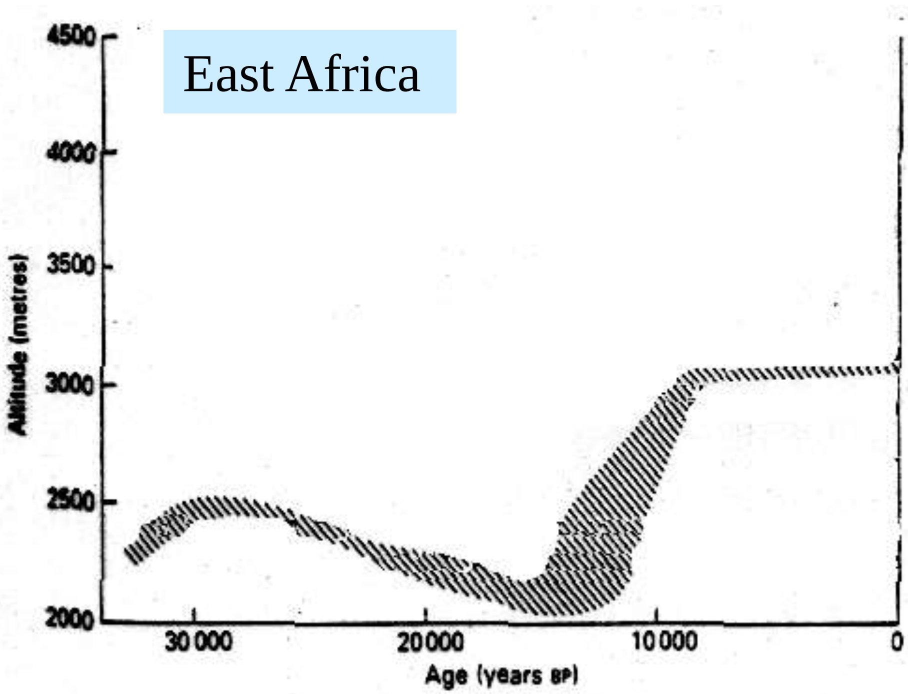


Fig. 6.12. Vegetation zones on the Andes near Bogota, Colombia. Compared to (a) the present day, the zones were (b) both depressed and compressed at the last Glacial maximum. (After van der Hammen in Flenley 1979, fig. 4.27.)

Changes in the upper forest limit during late Quarternary





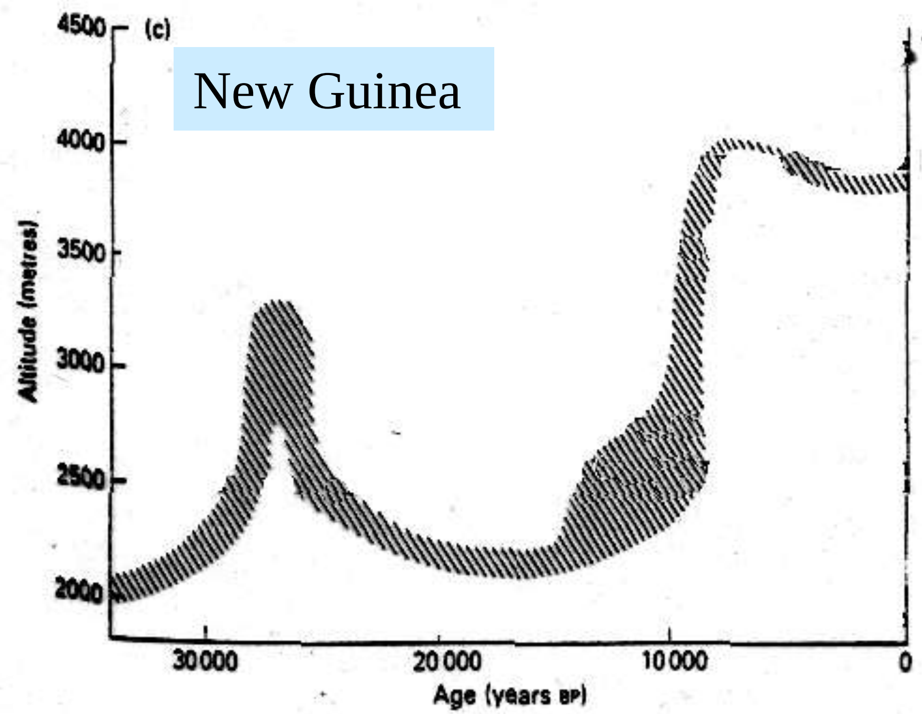
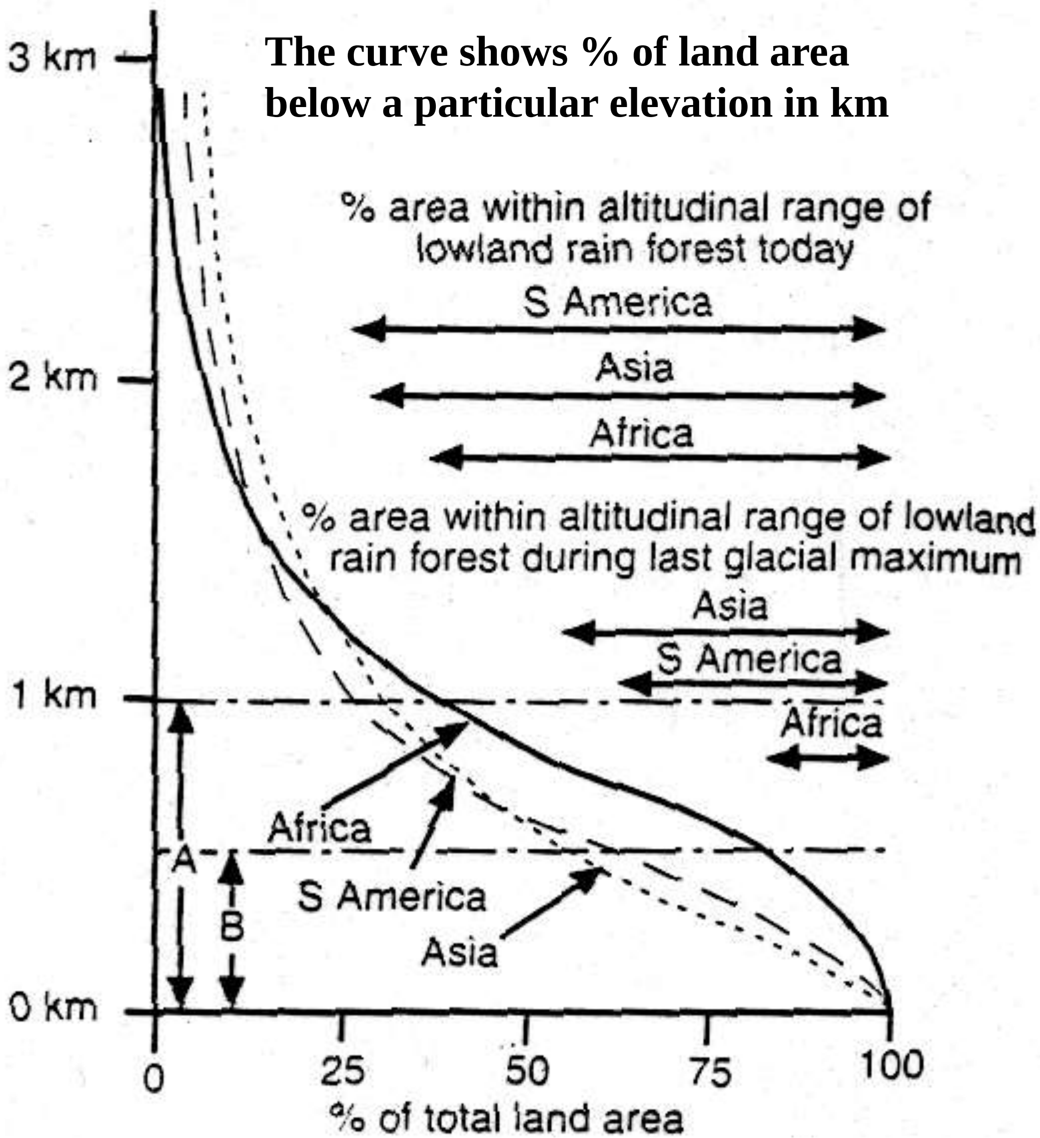


Fig. 6.11. Oscillations in the upper limit of forests during the late Quaternary in (a) the Colombian Andes, (b) the mountains of east Africa, and (c) the New Guinea highlands. (After Flenley 1979, figs. 4.26, 3.24, 5.23.)

Continental altitudinal profiles: high elevations in Africa lead to smaller lowland rainforest areas during glacial maximum

The curve shows % of land area below a particular elevation in km

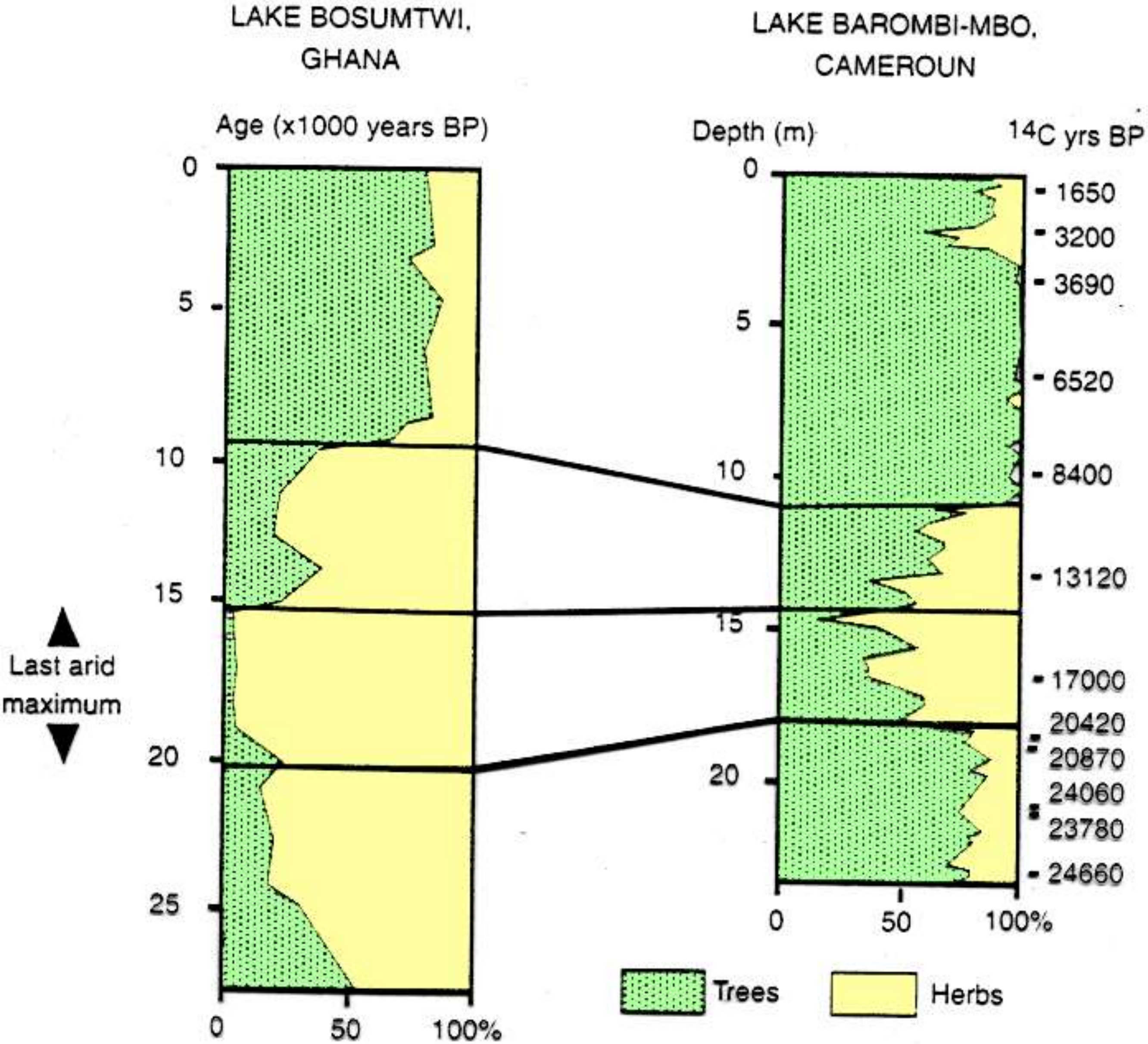


During the last glacial maximum, only 15% of land area in Africa was in the lowland rainforest zone, compared to 35% in S. America and 40% in Asia

AND

tropical forests in Africa are now the least diverse...

Figure 7.1 Normalised hypsographic curves for Africa, South America and Asia, comparing their relative elevations (Harrison et al., 1981). During the Holocene, about 60% of the area of the African continent lay within the altitudinal range of tropical rain forest, compared to about 70% in South America and Asia (delimited by 'A'). During the last glacial maximum, with tropical rain forests possibly depressed by 500 m (see Section 7.7), 40% of the area above present sea level in Asia and 35% in South America was within the altitudinal range of tropical rain forest (delimited by 'B'), but in the more elevated African continent only 15% of the land area would have been within this altitudinal range. It is clear that the limited representation of low altitude terrain needs to be given as much consideration as moisture reduction in explaining diversity loss in African tropical rain forests.



Forest area change in past 20,000 yr in Africa

pollen from lake sediments

7.20 Summary pollen diagrams for Lake Bosumtwi, Ghana, and Lake Barombi-Mbo, Cameroun (Maley, 1996). Reproduced by permission of the author and Royal Society of Edinburgh.

Conclusions:

The present distribution of tropical forests is very recent and most species evolved in different places than those they are facing now.

Current decrease in rainforest area has a recent precedent - during past glacial maximum, only 18,000 years ago.

The present-day rainforest ecosystems are therefore not venerable finely-tuned systems, but rather hastily assembled makeshift contraptions.

This last point is well explained in:
Daniel H. Janzen (1985) On ecological fitting. Oikos 45: 308.