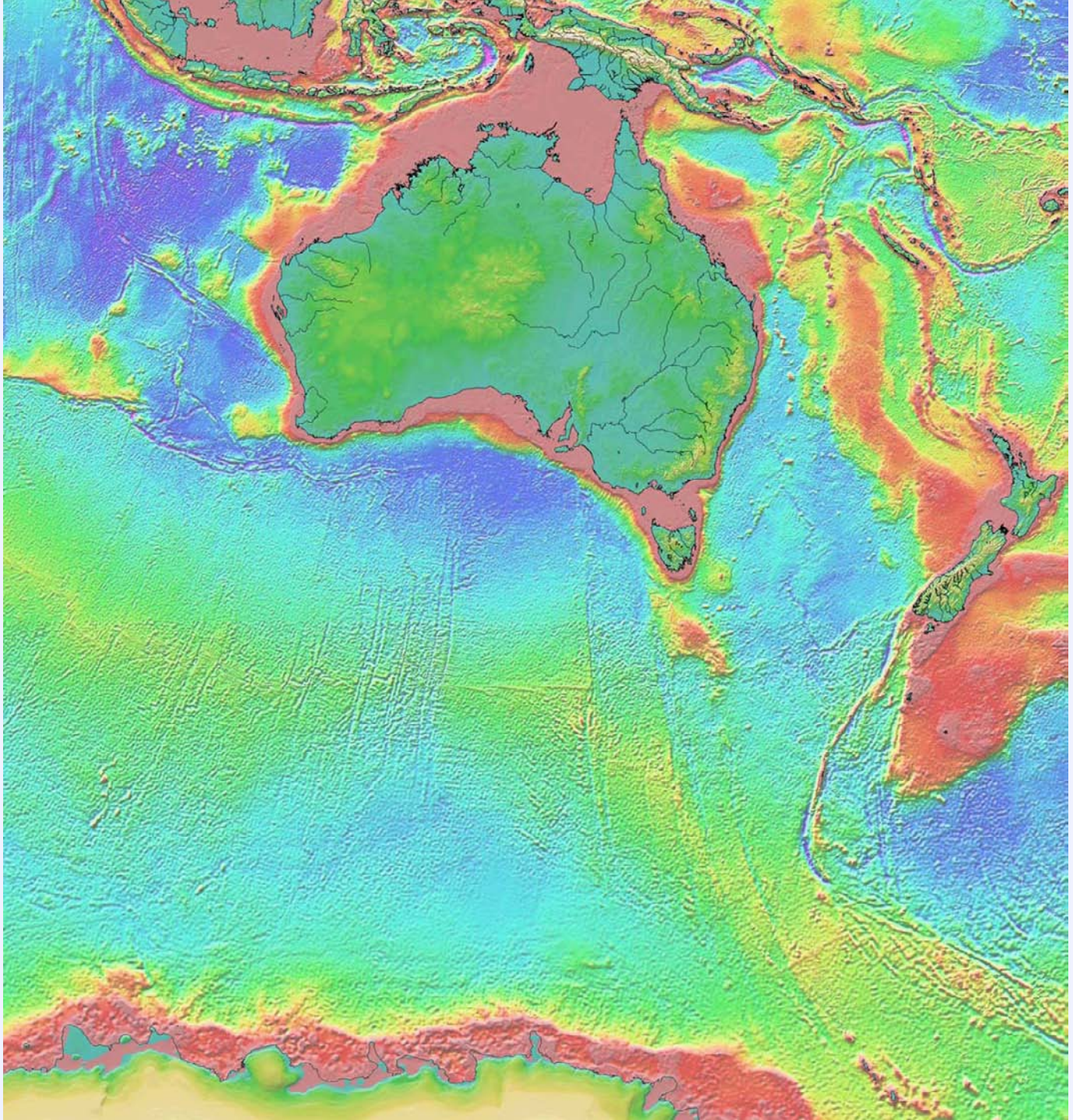

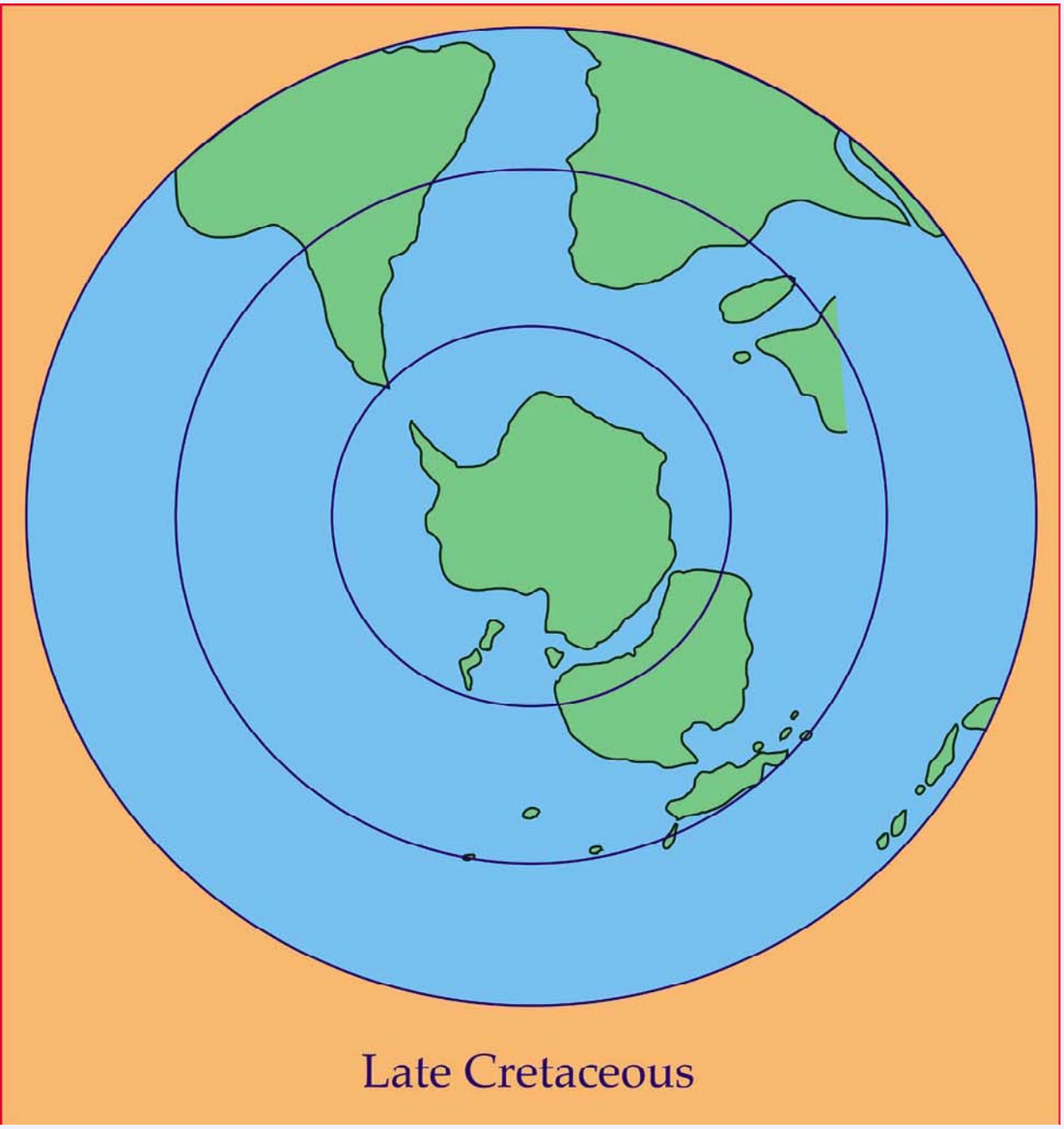

Gondwana about 120 million years ago

- Australian rainforests have their origins in the Cretaceous, about 80 million years ago, and probably reached their peak diversity during a period of optimal climate around 40-25 mya

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- Many living genera were present then and rainforest diversity was much higher than today

- What happened to these rainforests?

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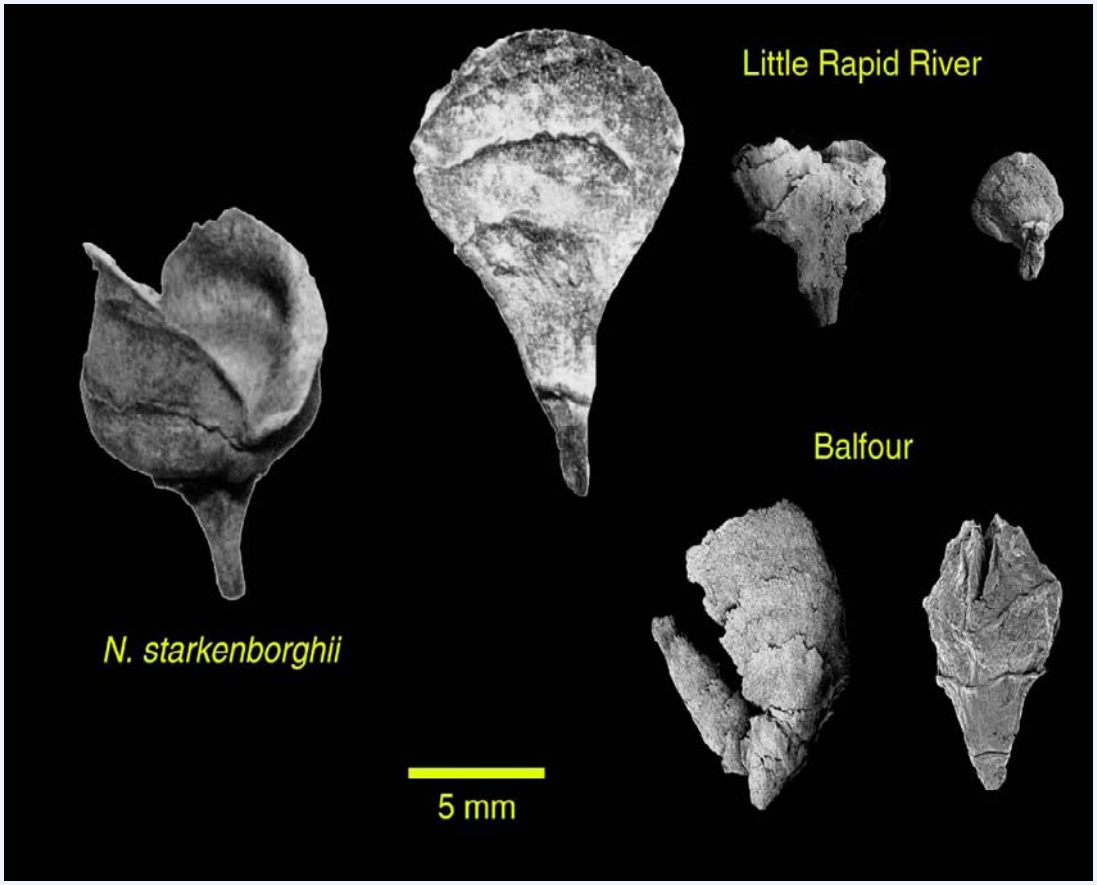
- The geographic area we know best is Tasmania

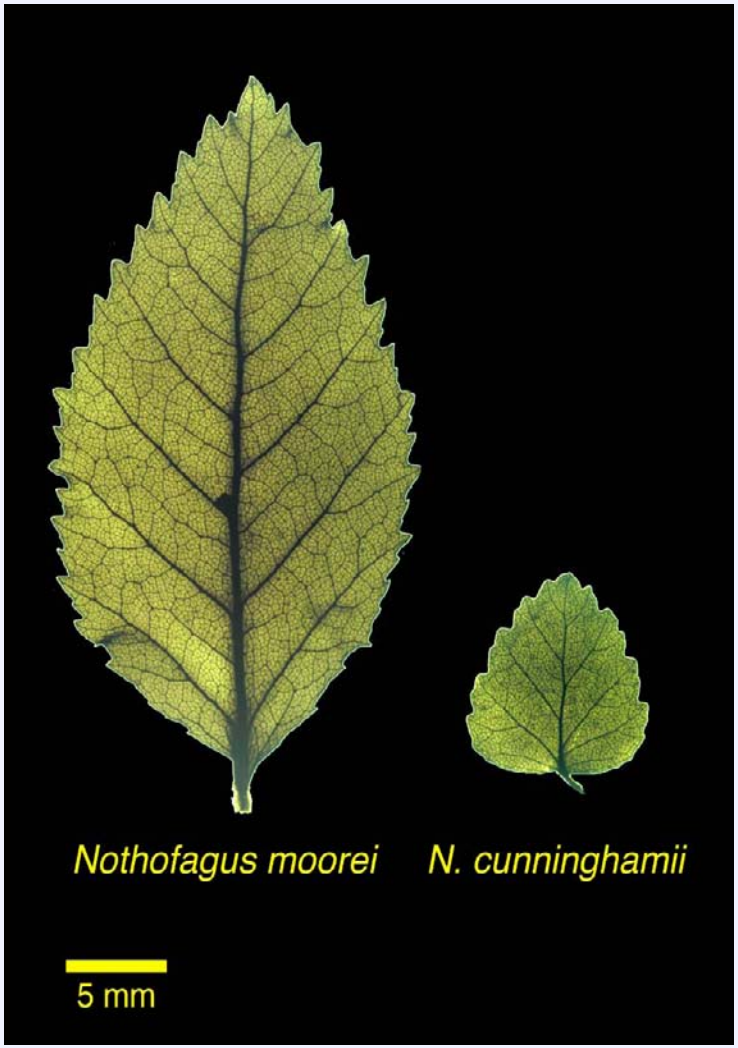
- What happened to these rainforests?
- The geographic area we know best is Tasmania
- The once highly diverse and complex Tasmanian rainforests simplified over a long time in response to a deteriorating climate by doing the following:

Some species migrated northwards into the tropics



Cupules of *Nothofagus* subgenus *Brassospora*

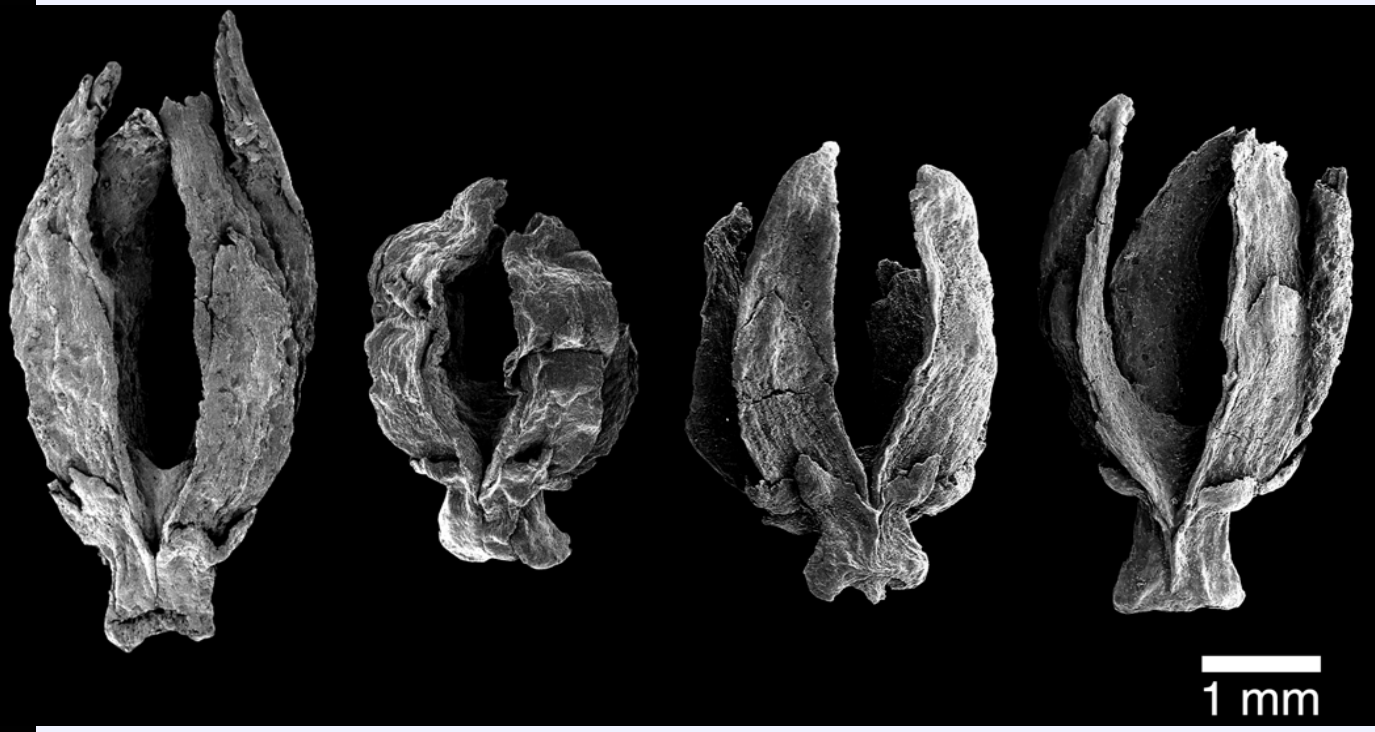
Some species migrated northwards but left highly evolved descendants in place



Nothofagus moorei now occurs in northern NSW, and obviously has much larger leaves than the Victorian/ Tasmanian *N. cunninghamii.*

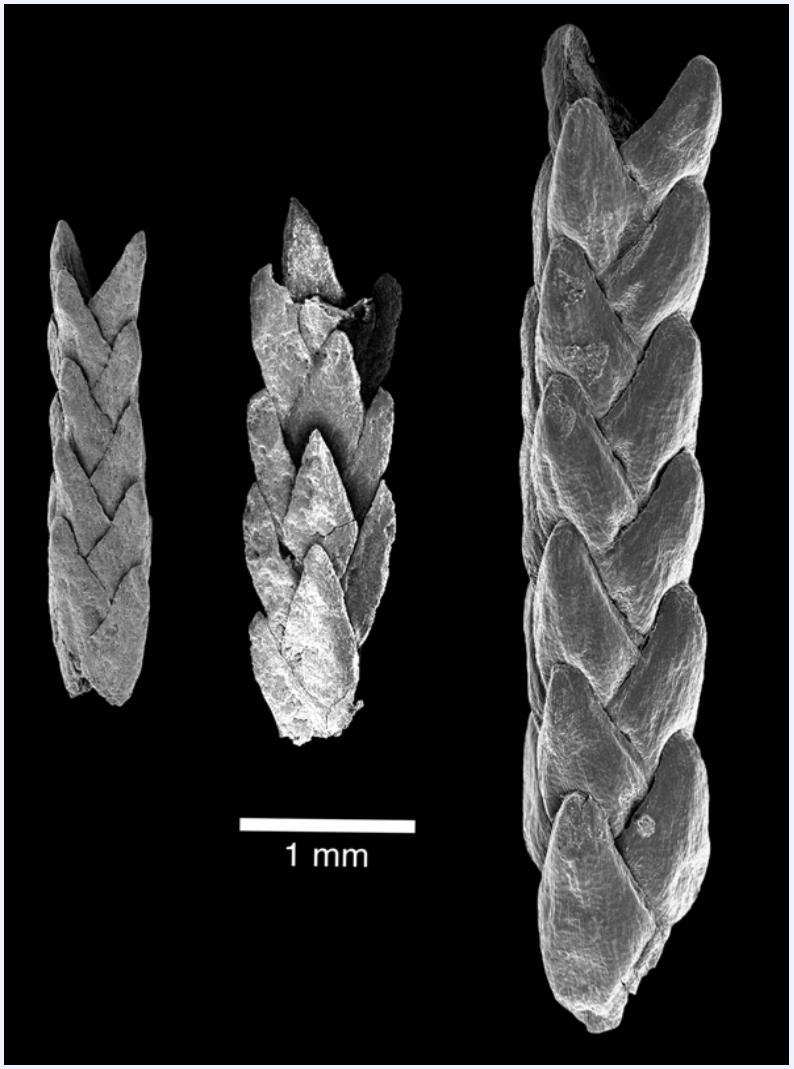
Other species pairs include *Acradenia euodiiformis* (NSW) and *A. frankliniae* (Tas.); *Anopterus macleayanus* (NSW) and *A. glandulosus* (Tas.); *Eucryphia moorei* (NSW) and *E. Lucida*/*E. milliganii* (Tas.)

Some species became extinct in Australia, but survive in landmasses at similar latitudes



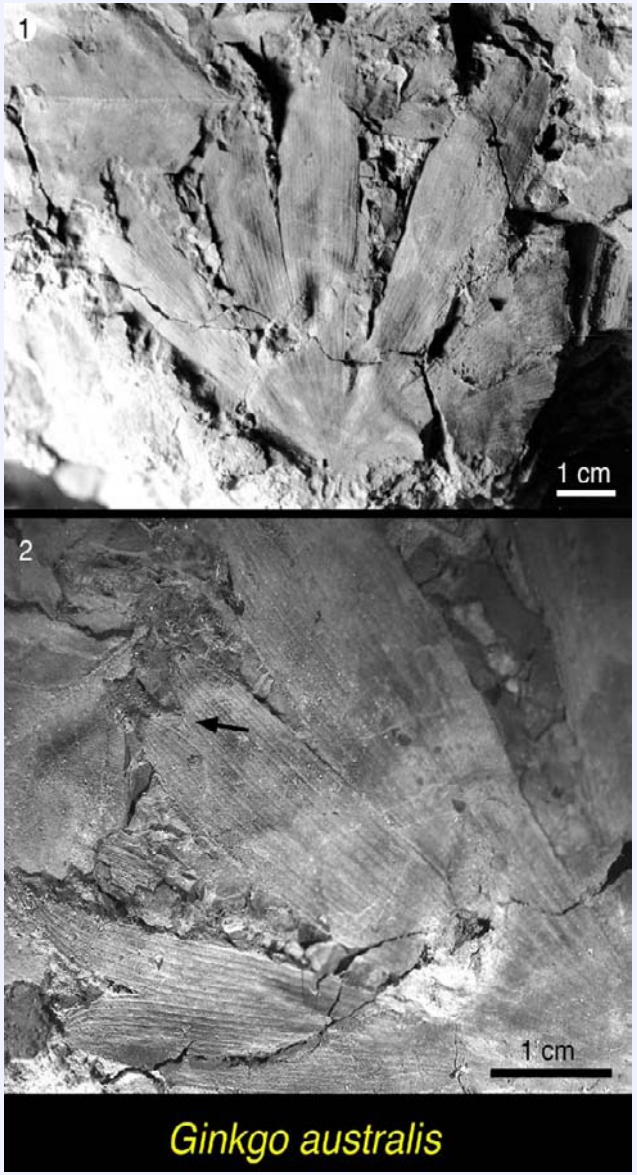
Leaf and cupule fossils of *Nothofagus* subgenus *Nothofagus* from the Early Oligocene of Tasmania

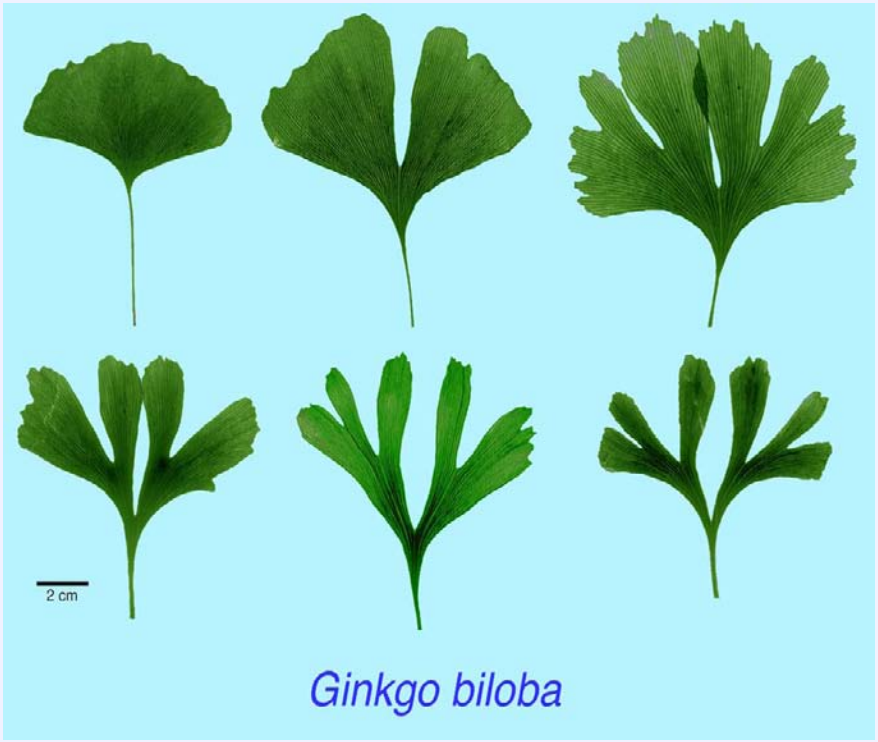
Some species remain more-or-less unchanged in the region



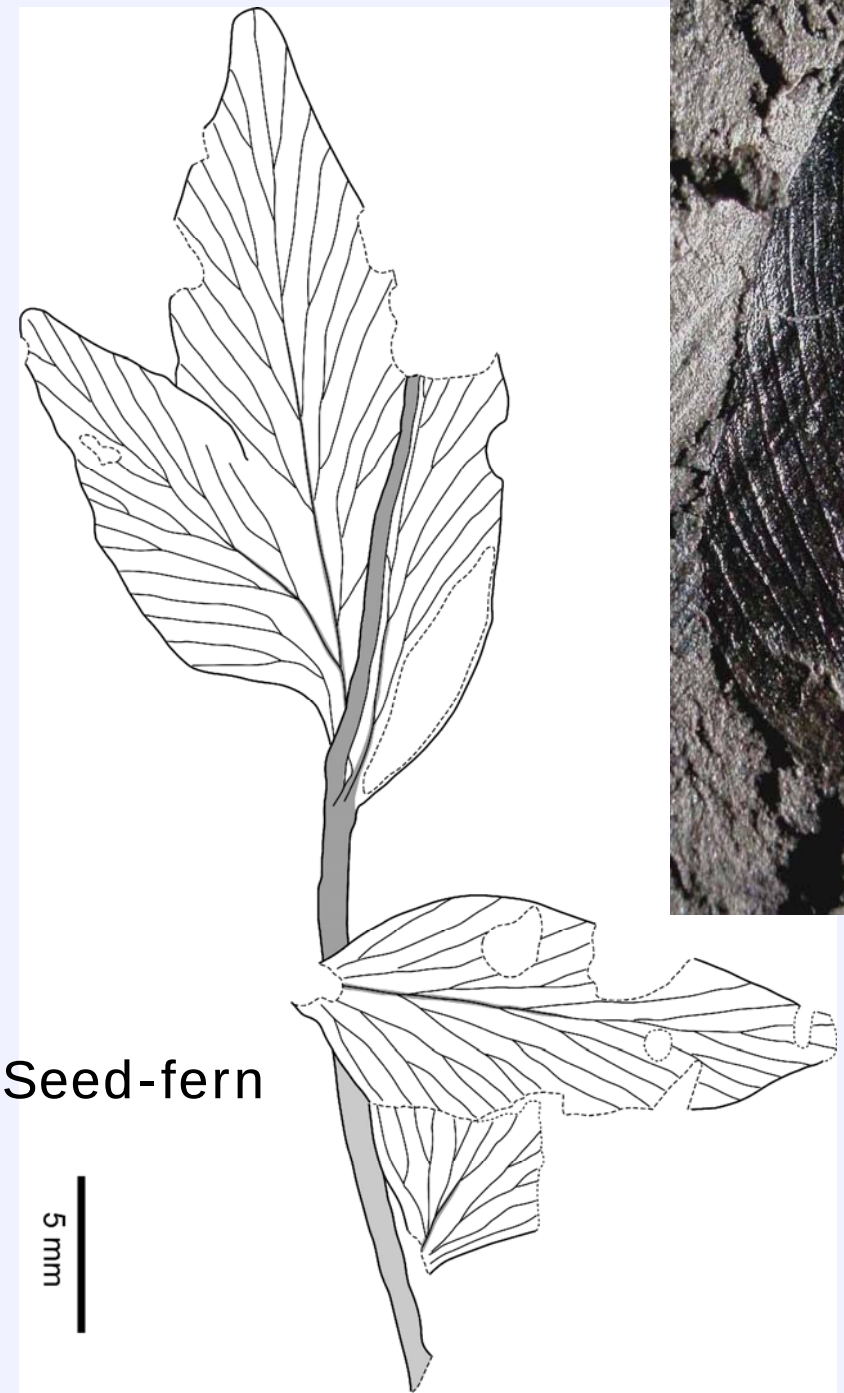
Diselma, Balfour (Oligocene, left), Little Rapid River (Early Oligocene, middle), extant (right)

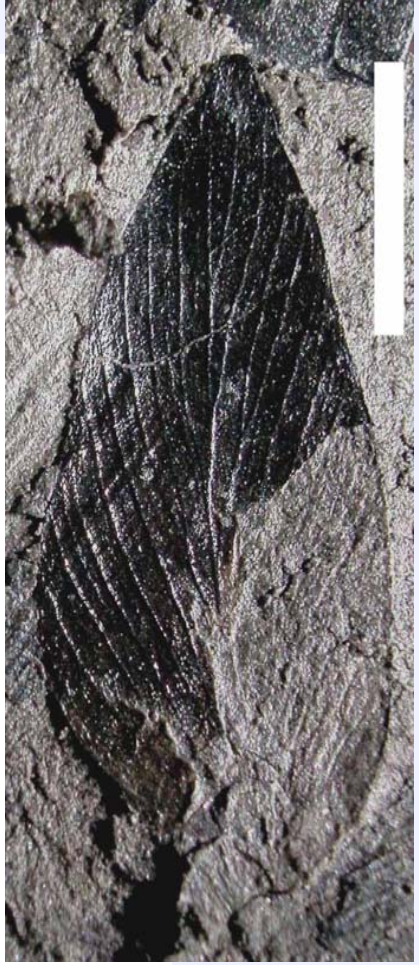
Some species became extinct, either globally or in the Southern Hemisphere

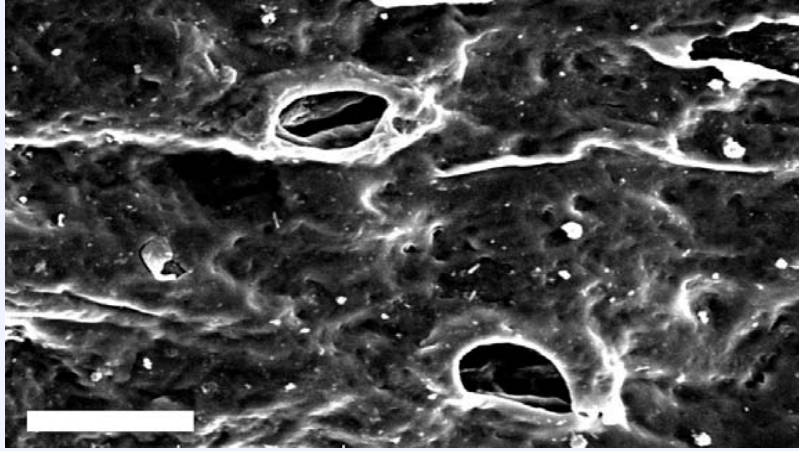


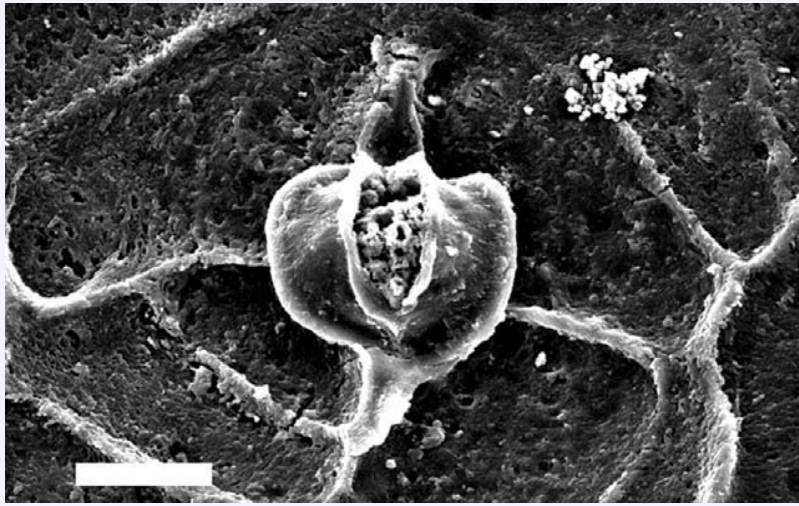


Ginkgo leaf fossil from the Paleogene of Tasmania (left) and living *G. biloba* leaves (above)


Seed-fern
5 mm







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- An extinct climate, characterized by high, year-round rainfall, with no dry season and a compression of temperature extremes.
- Extremely high atmospheric carbon dioxide levels.

Rainforest was extensive across much of Australia 35 mya. Why did this change?

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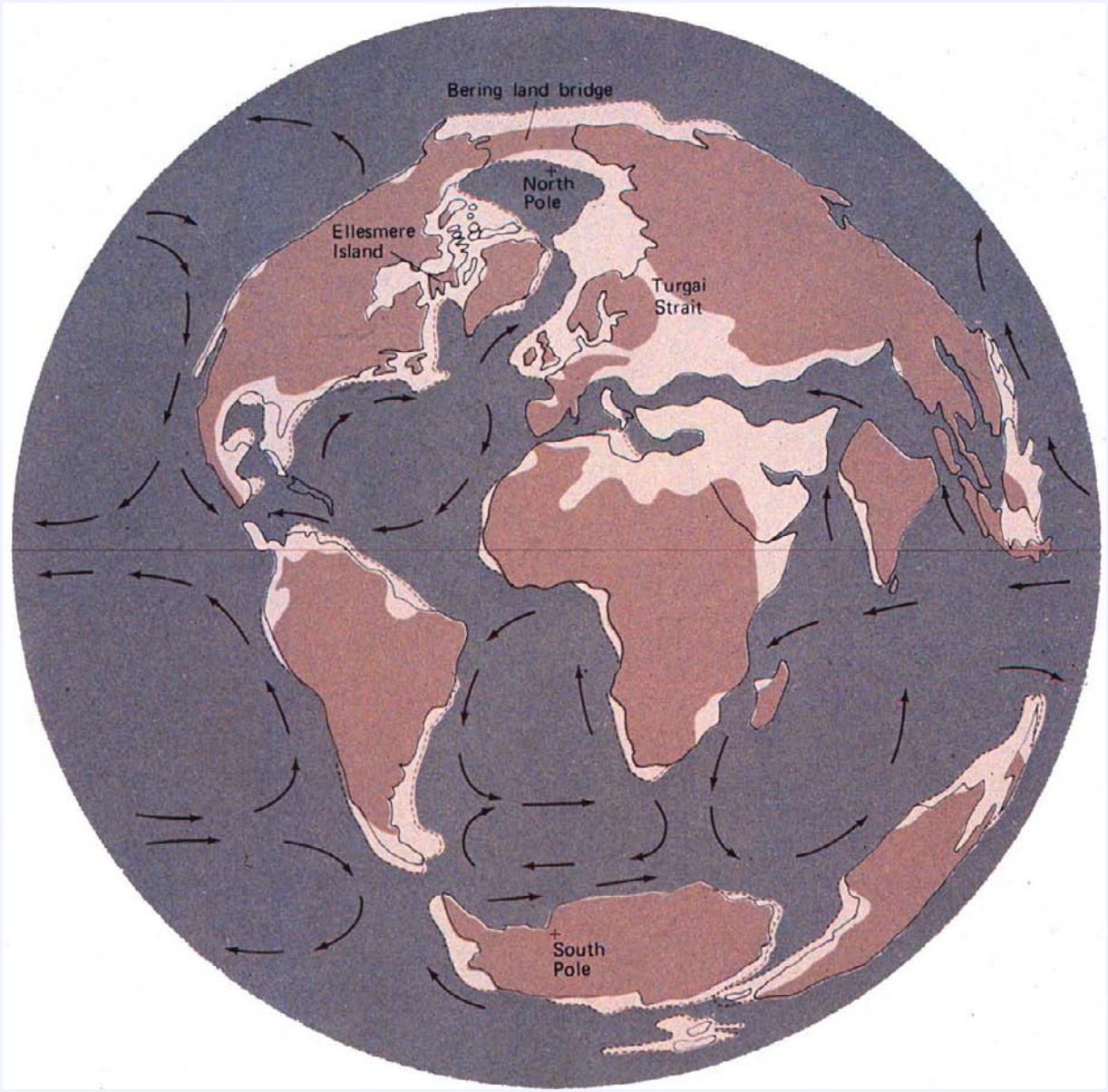
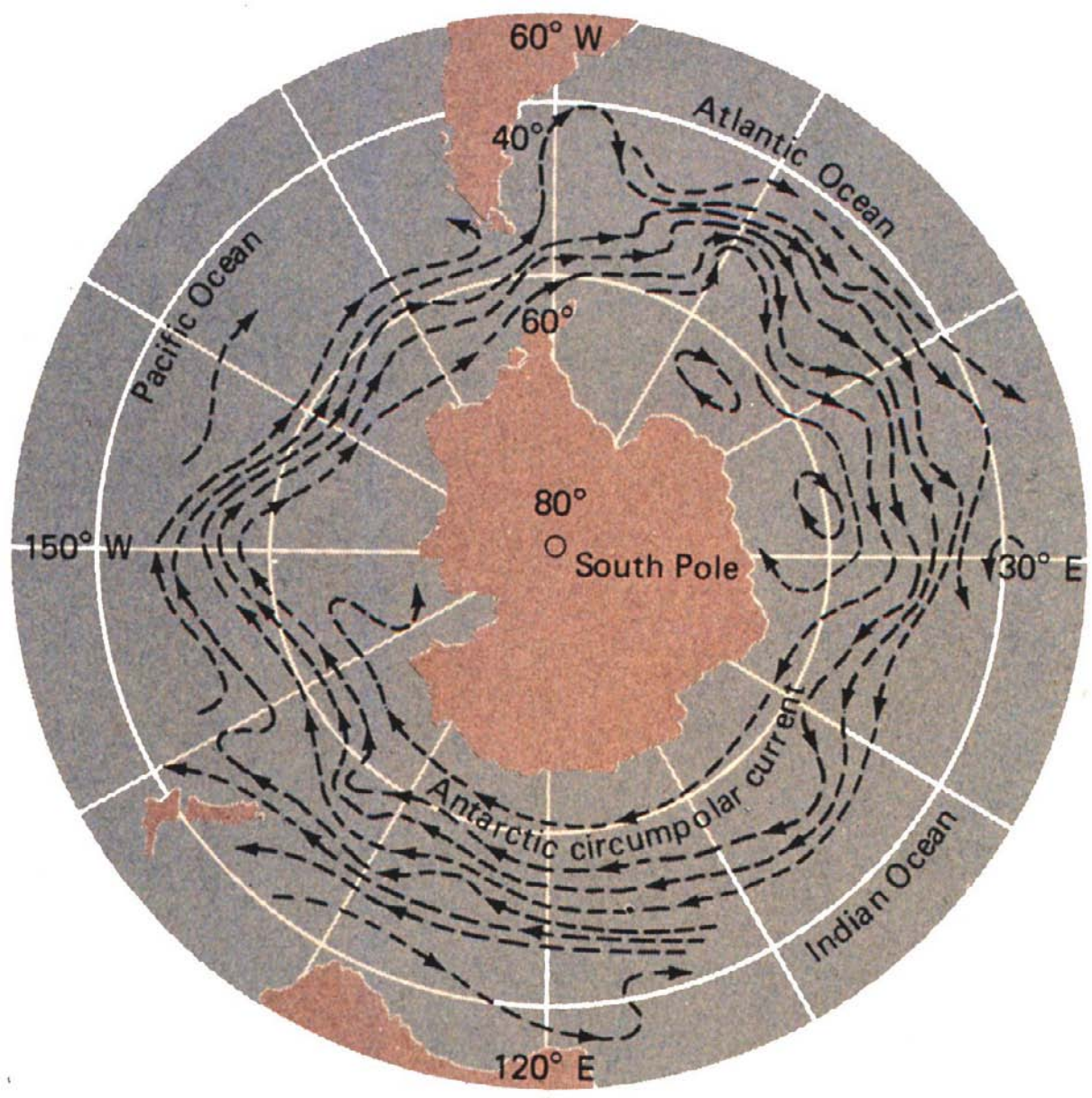
- Temperatures changed, and most importantly, temperature extremes increased in both directions.

- As a result of the climate changes, fire increased in significance in Australia.

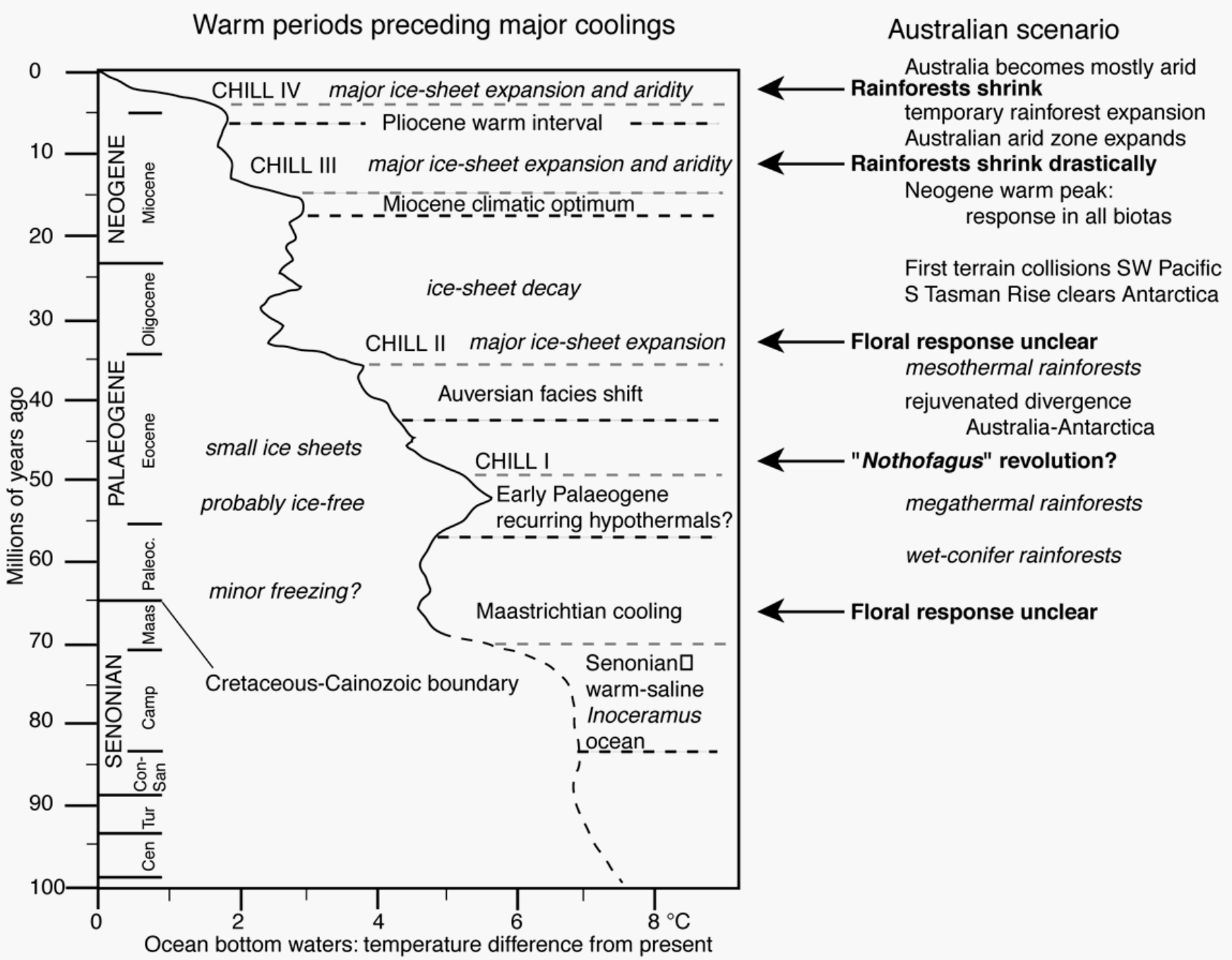
Palms in central Australia around permanent water sources are probably a relict of earlier, wetter times.

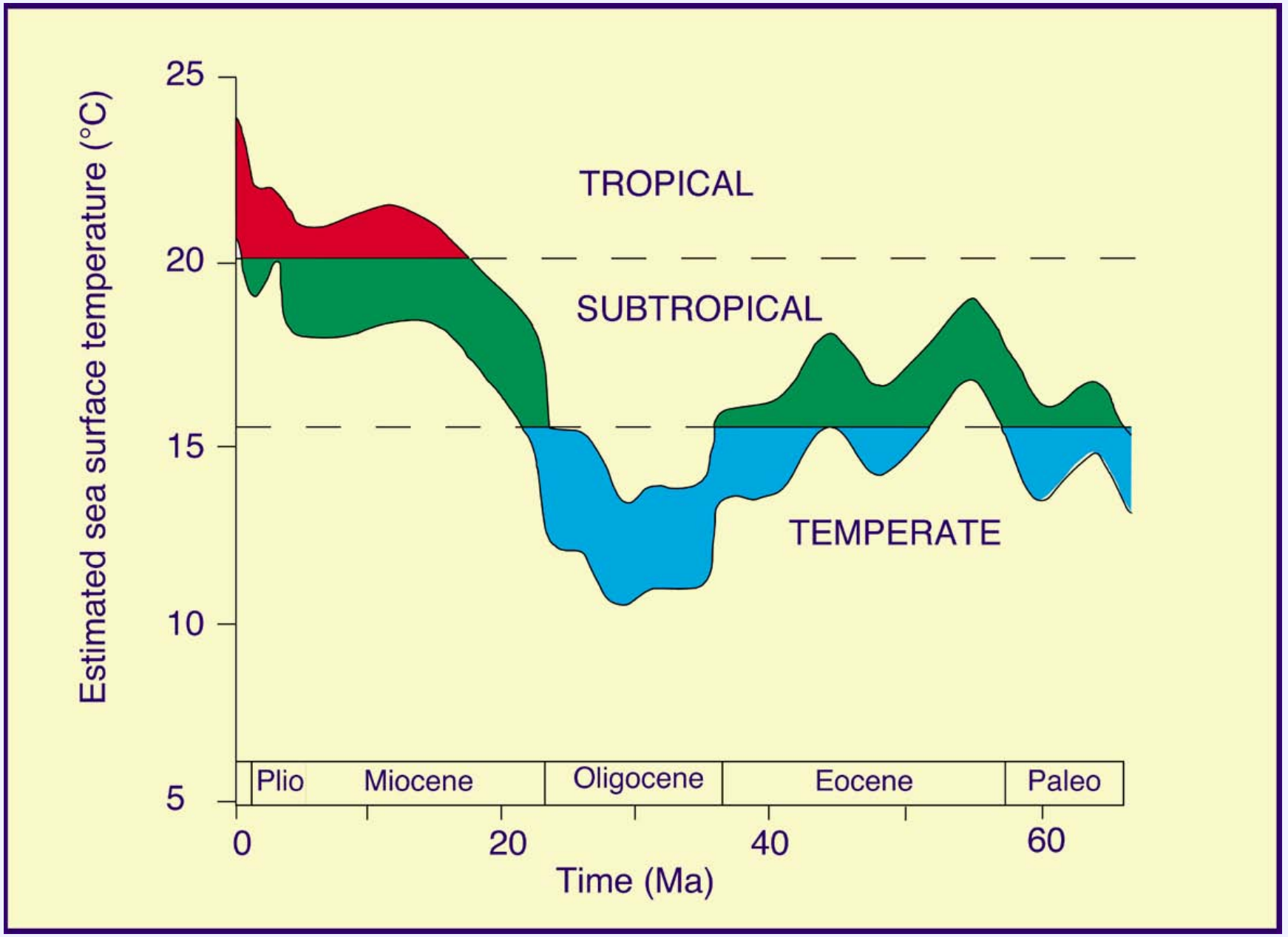


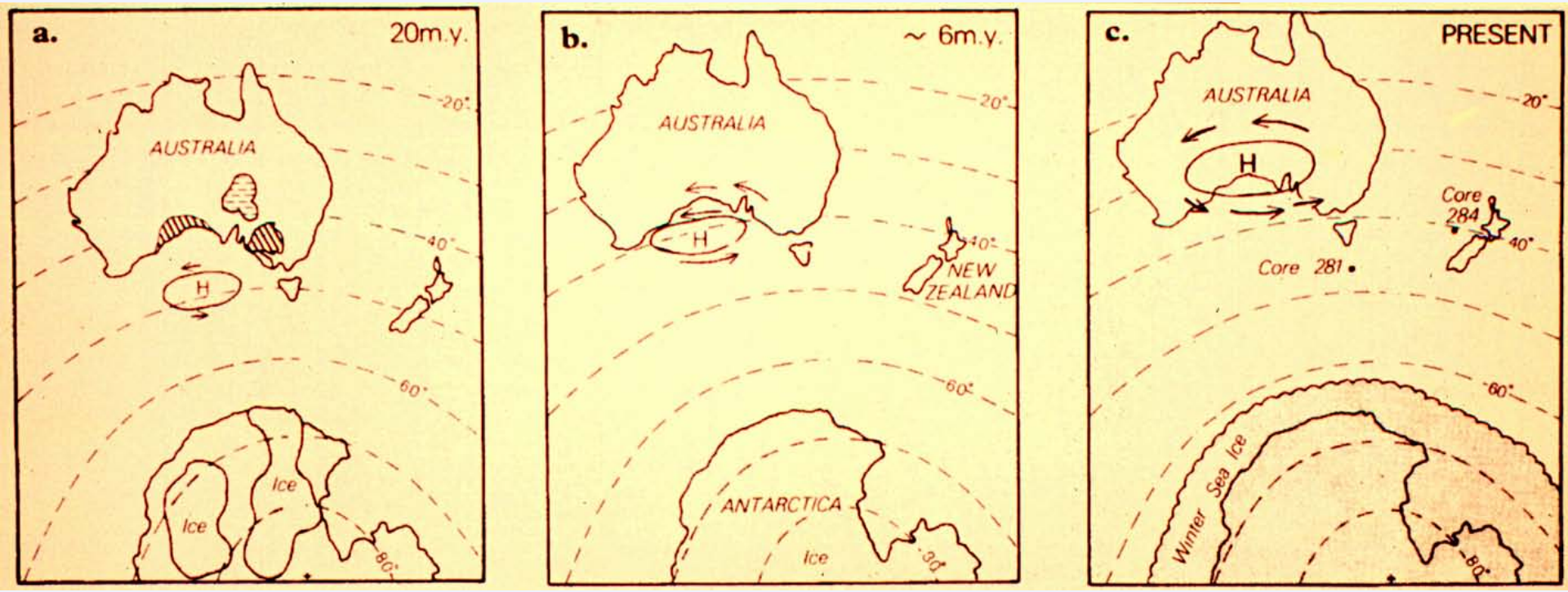
Late Eocene ocean circulation patterns



Modern ocean circulation patterns


Warm periods preceding major coolings
Australian scenario
Millions of years ago
0
10
20
30
40
50
60
70
80
90
100
NEOGENE
PALAEOGENE
SENONIAN
Miocene
Oligocene
Eocene
Paleoc.
Maas
Camp
Con-San
Tur
Cen
CHILL IV major ice-sheet expansion and aridity
Pliocene warm interval
CHILL III major ice-sheet expansion and aridity
Miocene climatic optimum
ice-sheet decay
CHILL II major ice-sheet expansion
Auversian facies shift
small ice sheets
CHILL I
probably ice-free
Early Palaeogene
recurring hypothermals?
minor freezing?
Maastrichtian cooling
Cretaceous-Cainozoic boundary
Senonian warm-saline Inoceramus ocean
0
2
4
6
8 °C
Ocean bottom waters: temperature difference from present
Australia becomes mostly arid
Rainforests shrink
temporary rainforest expansion
Australian arid zone expands
Rainforests shrink drastically
Neogene warm peak:
response in all biotas
First terrain collisions SW Pacific
S Tasman Rise clears Antarctica
Floral response unclear
mesothermal rainforests
rejuvenated divergence
Australia-Antarctica
"Nothofagus" revolution?
megathermal rainforests
wet-conifer rainforests
Floral response unclear


Estimated sea surface temperature (°C)
25
20
15
10
5
TROPICAL
SUBTROPICAL
TEMPERATE
Plio
Miocene
Oligocene
Eocene
Paleo
0
20
40
60
Time (Ma)

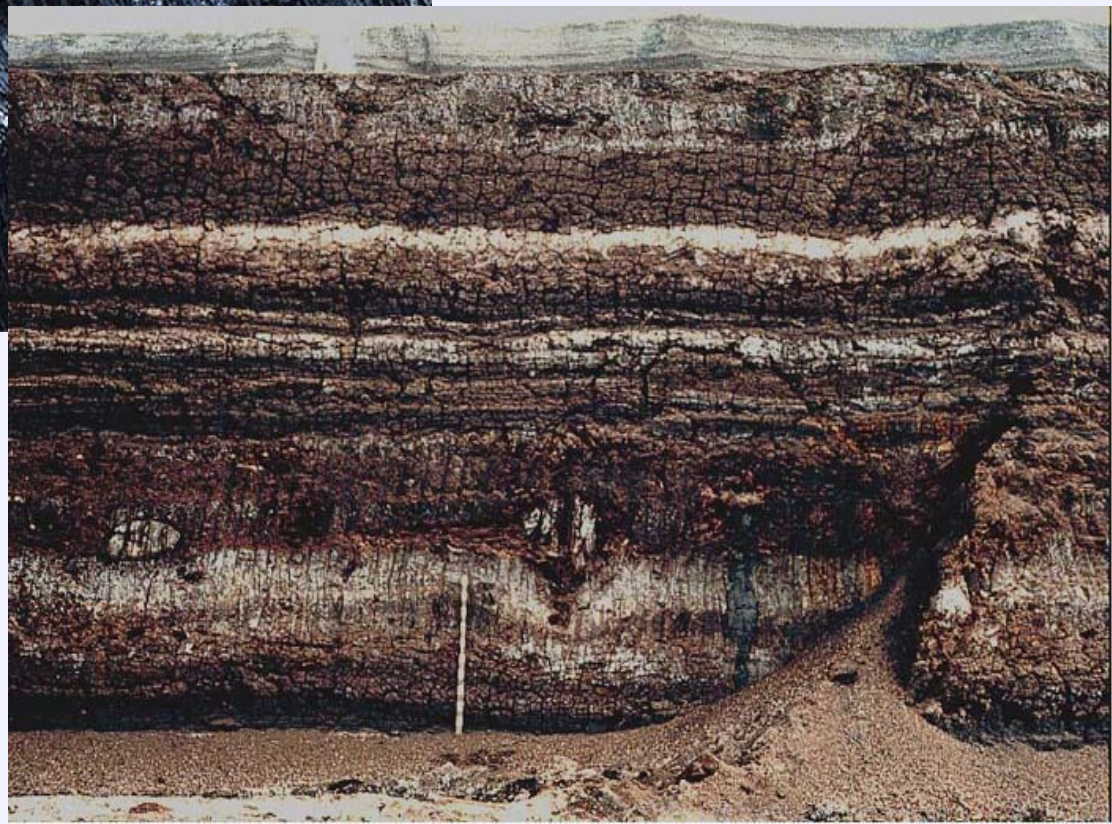


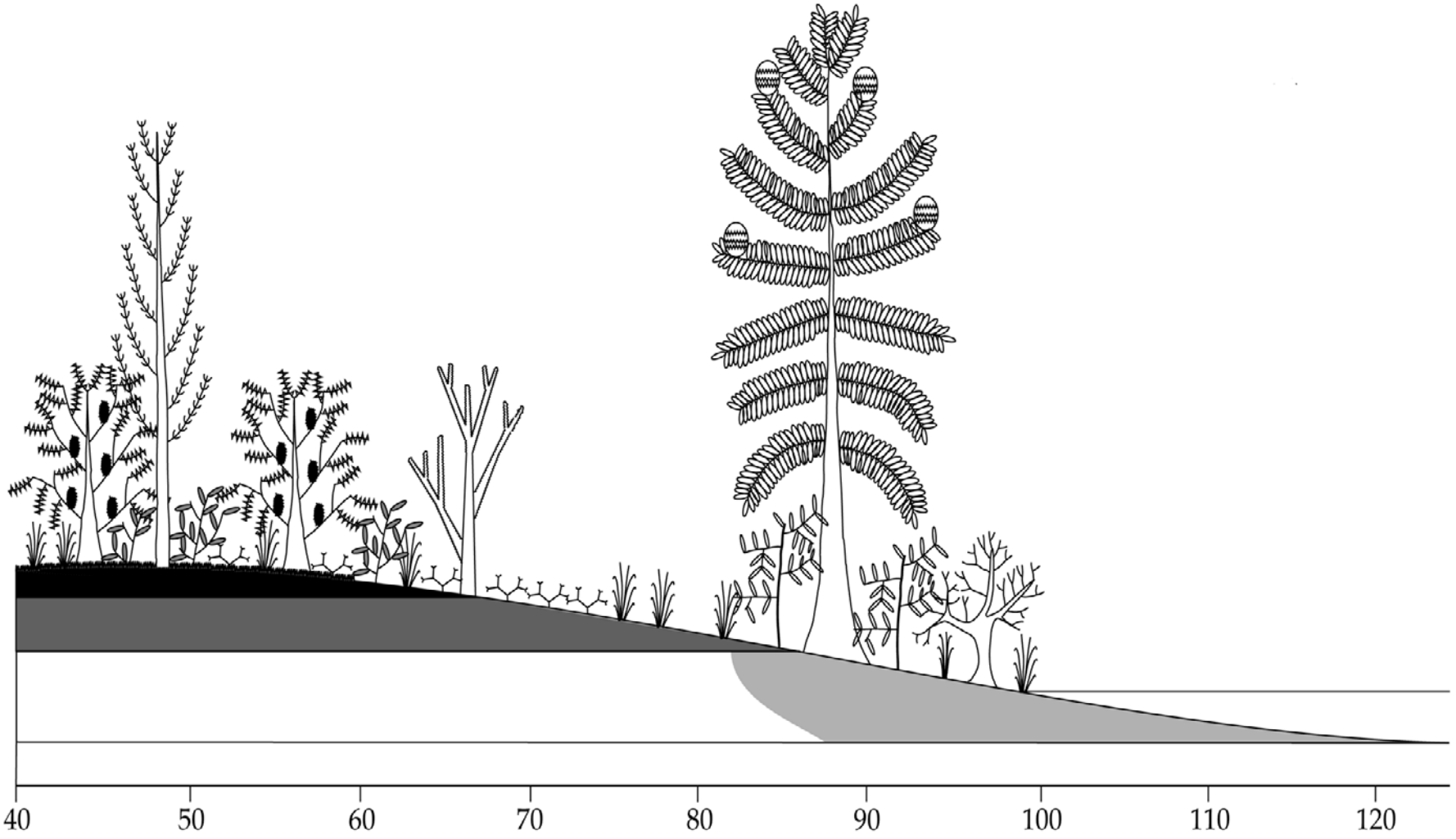
During the Cenozoic, the subtropical high pressure cell that controls the summer-winter rainfall boundary moved northwards faster than Australia.

With the drying out of Australia, plant litter accumulated, providing fuel for fires, and inevitably fire frequency and intensity increased.

Fire is an integral part of the Australian landscape

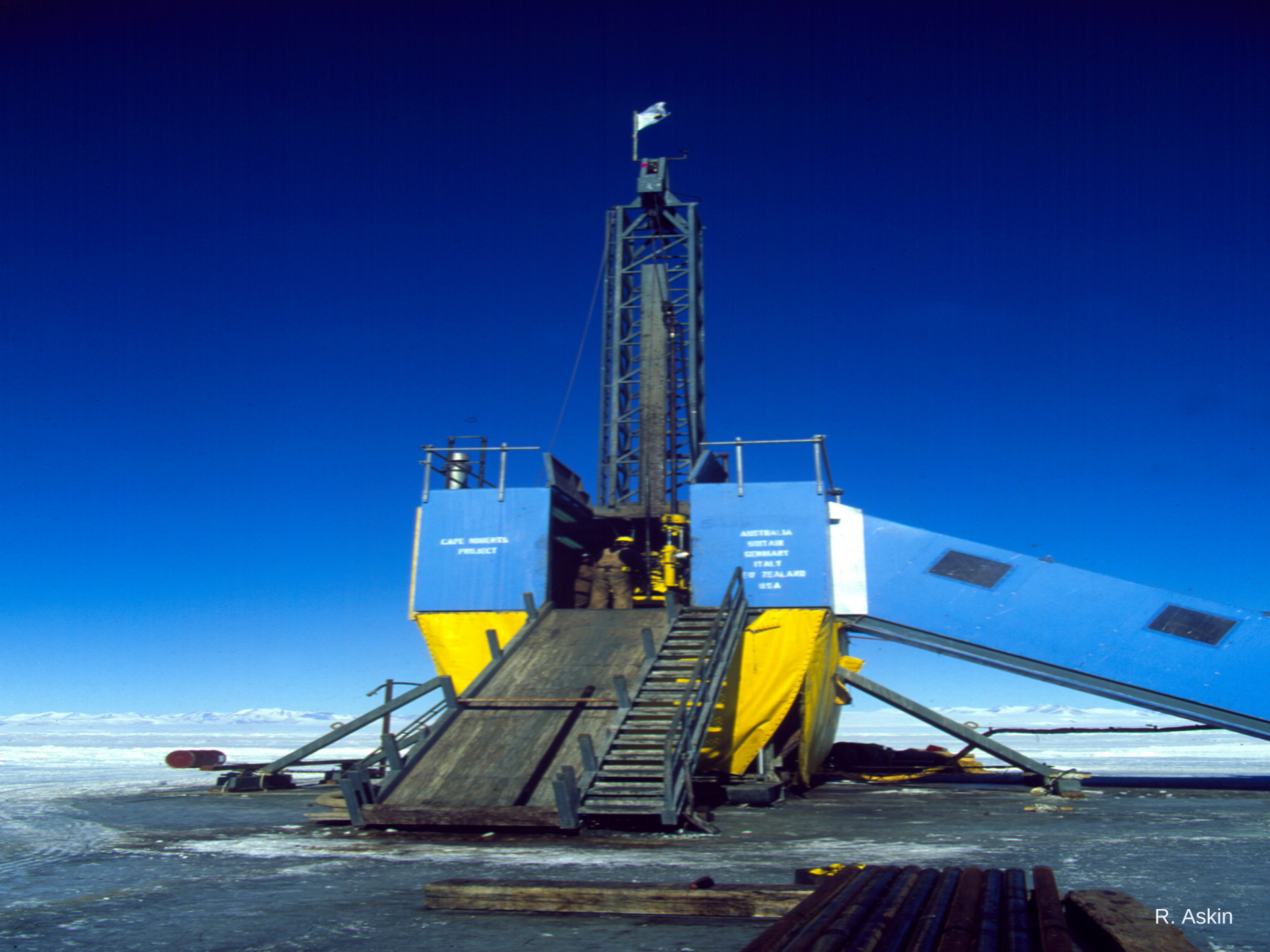
The Latrobe Valley coal offers a detailed insight into Australian fire history



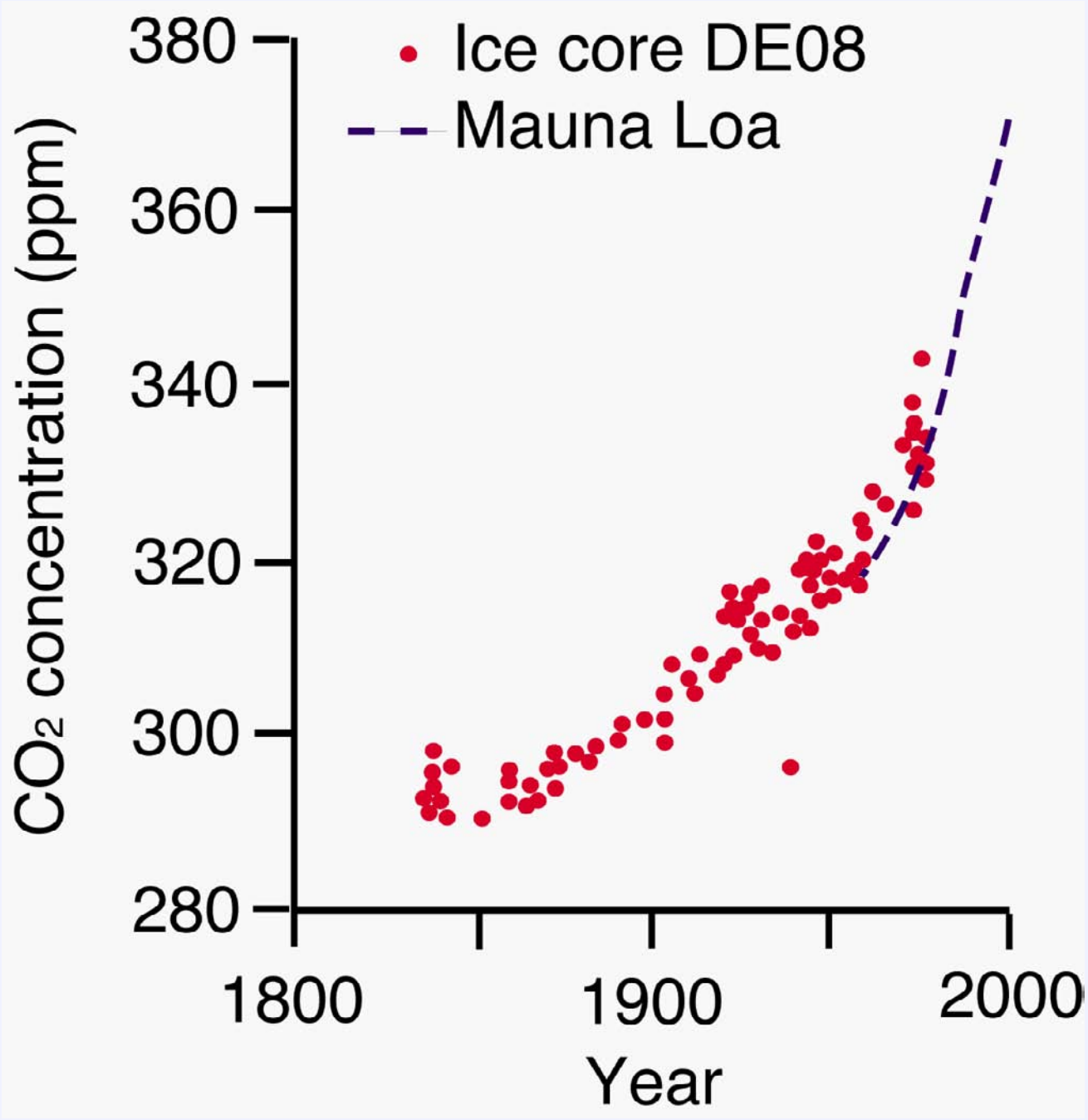


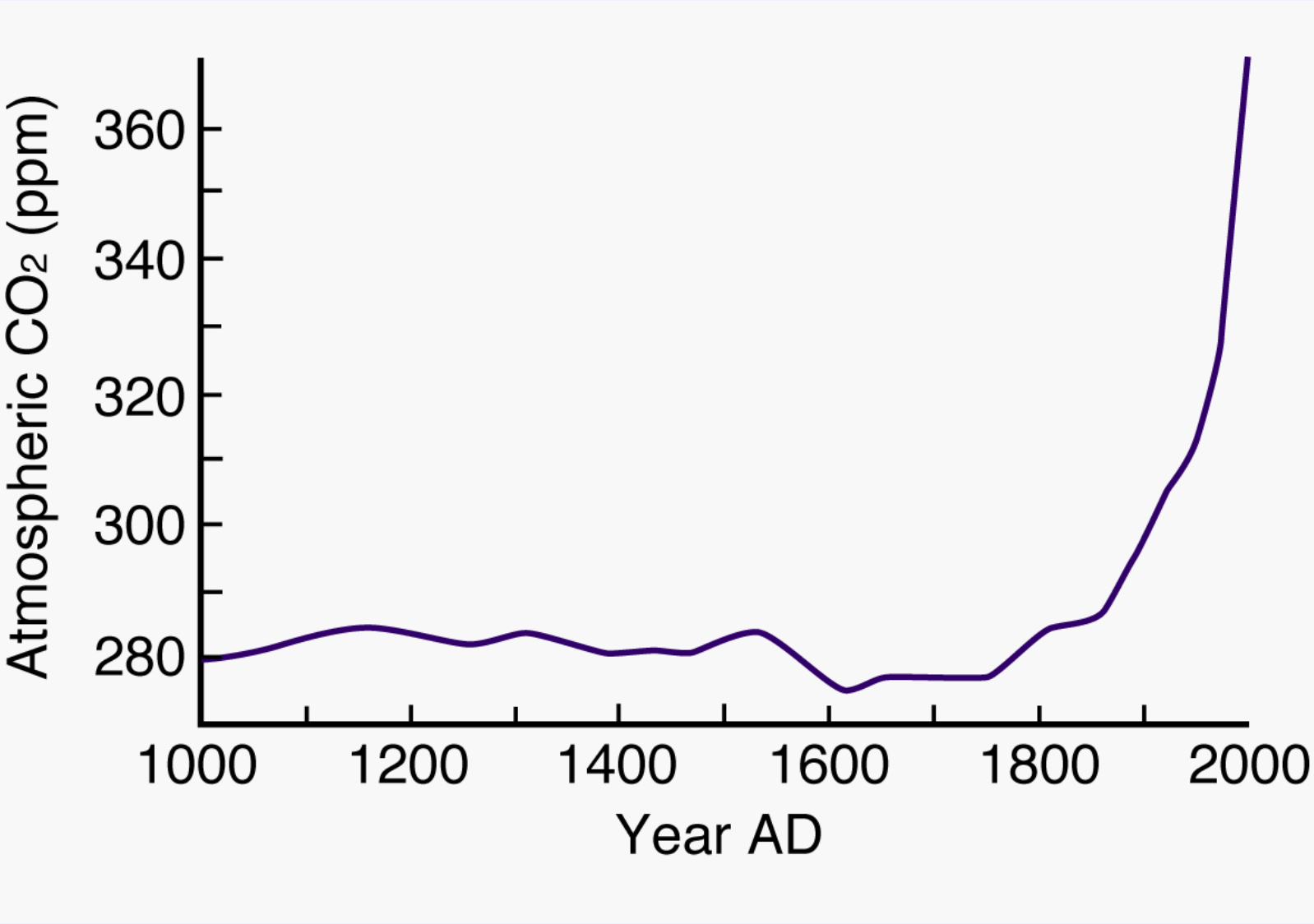
The transition from mesic to xeric vegetation with height above the water table in the LaTrobe Valley

Atmospheric carbon dioxide - the great unknown


CAPE ROBERTS
PROJECT
AUSTRALIA
GERMANY
ITALY
NEW ZEALAND
U.S.A.

R. Askin


Ice core DE08
Mauna Loa
380
360
340
320
300
280
CO_2 concentration (ppm)
1800
1900
2000
Year


Atmospheric CO_2 (ppm)
360
340
320
300
280
1000
1200
1400
1600
1800
2000
Year AD

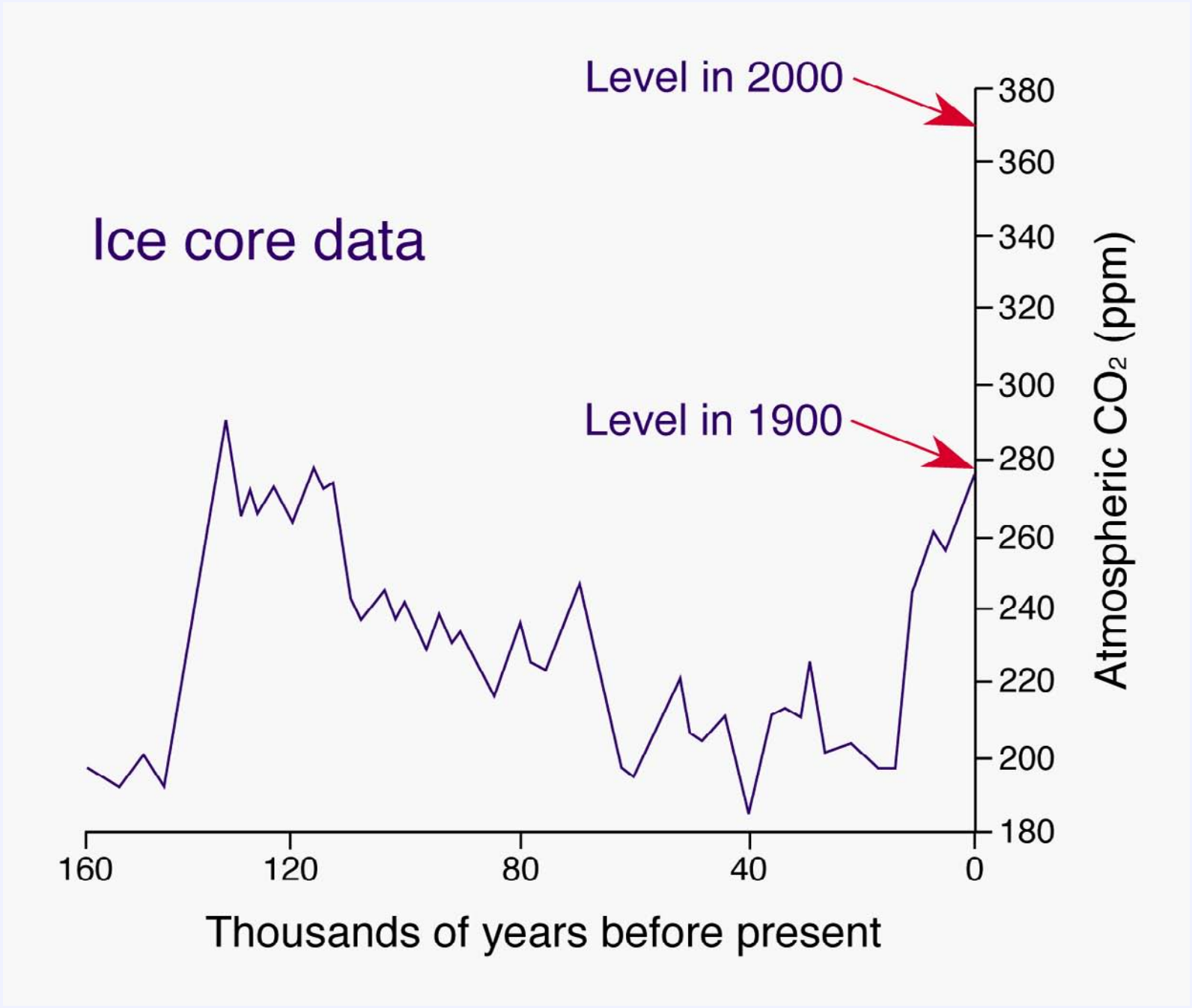
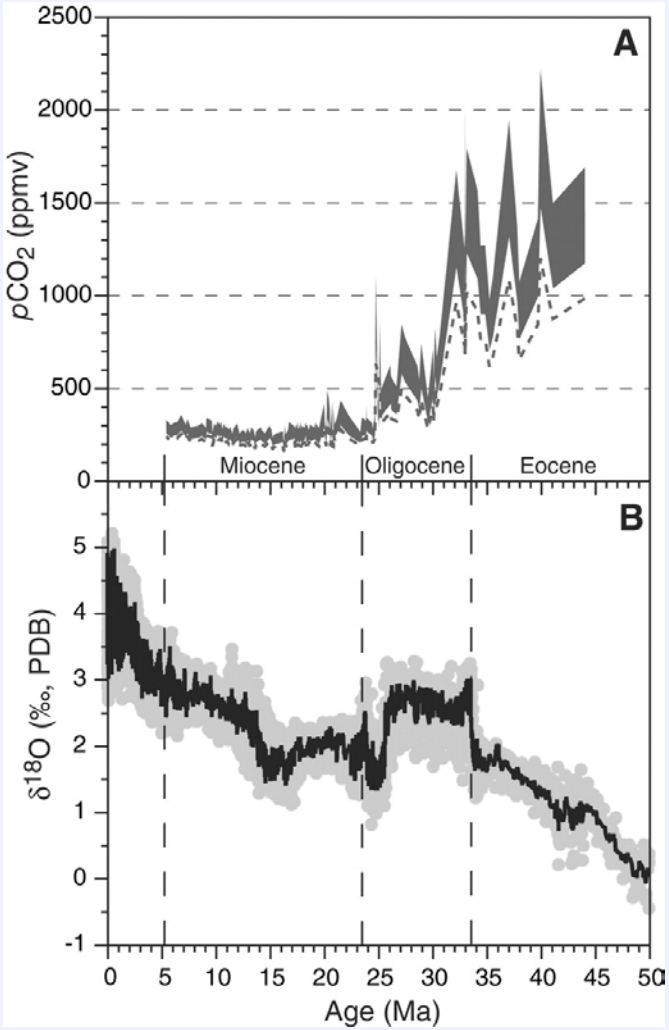
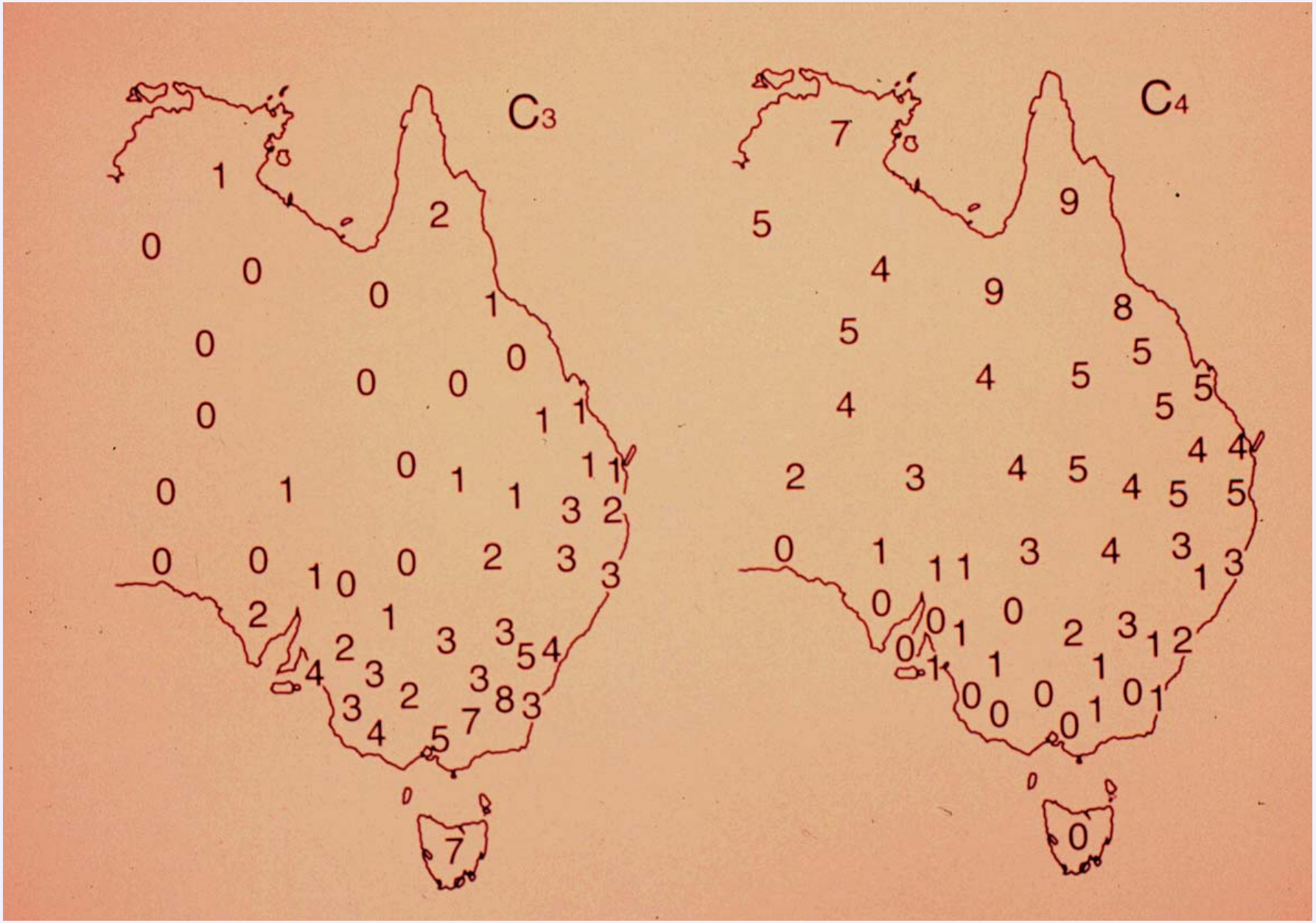

Level in 2000
Ice core data
Level in 1900
380
360
340
320
300
280
260
240
220
200
180
Atmospheric CO_2 (ppm)
160
120
80
40
0
Thousands of years before present

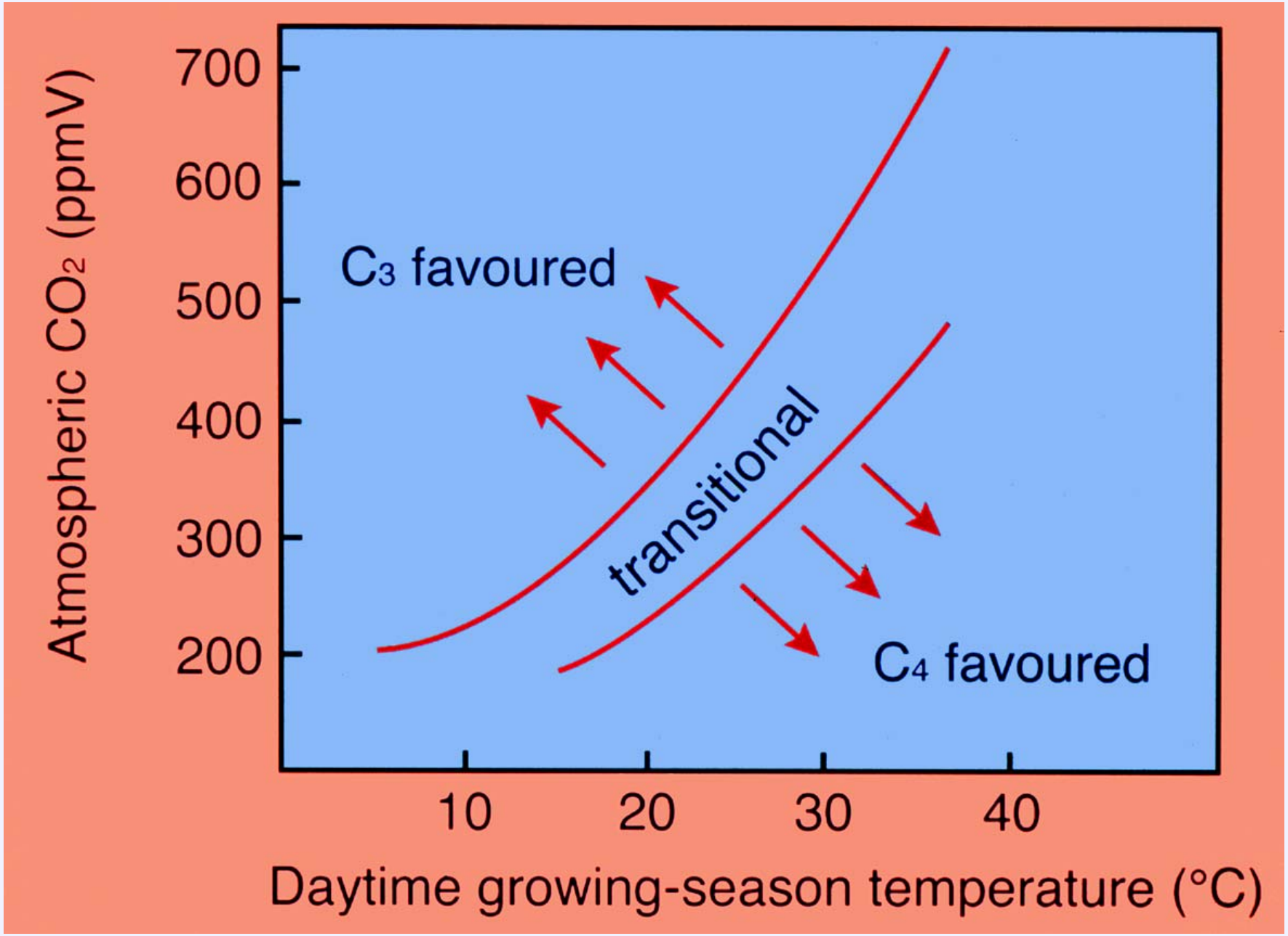
Fig. 3. (A) pCO2 estimates calculated from {epsilon}p37:2

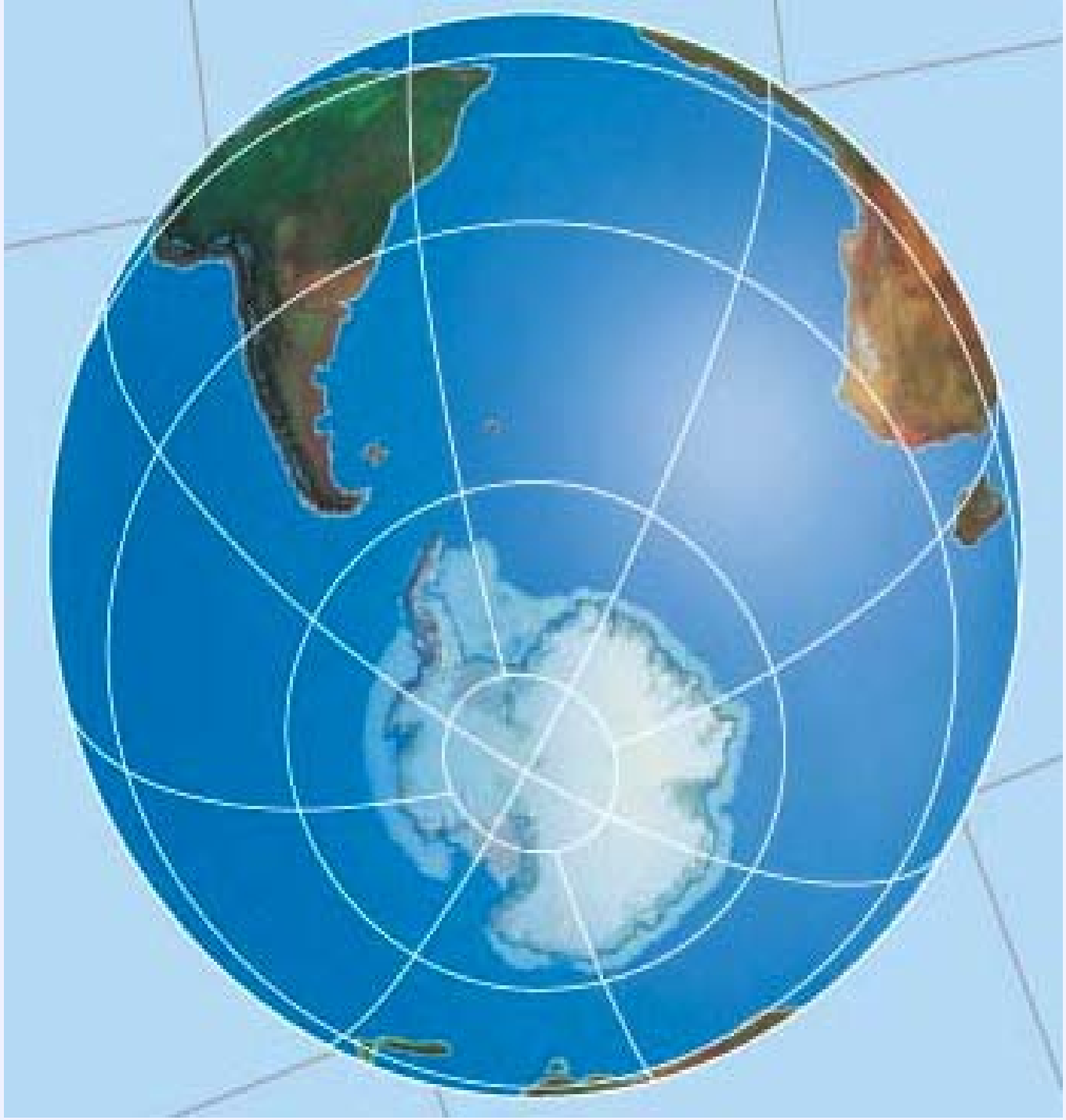


M. Pagani et al., Science 309, 600 -603 (2005)



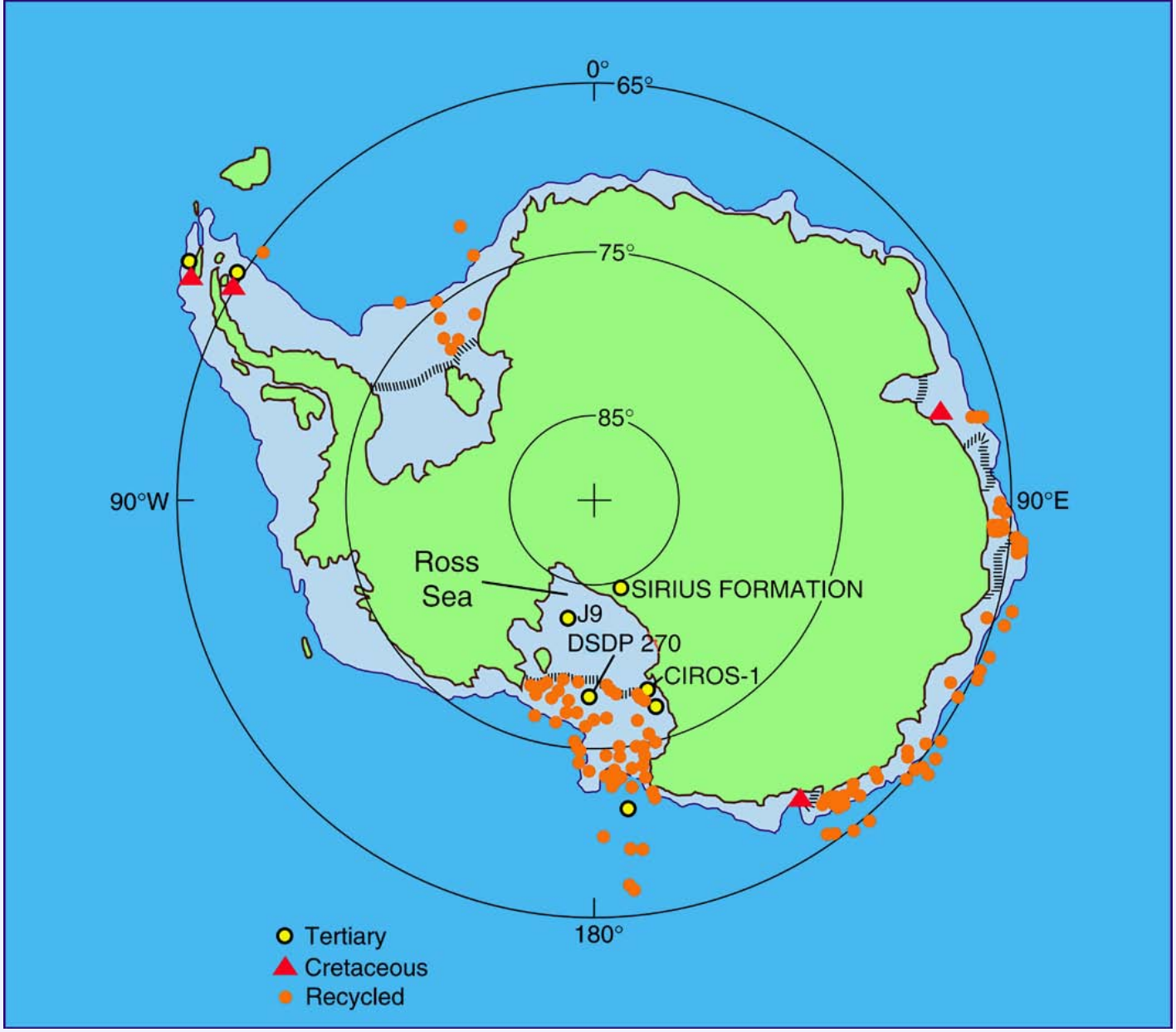
Relative proportions of C_3 and C_4 grasses in Australia


Atmospheric CO_2 (ppmV)
700
600
500
400
300
200
C_3 favoured
transitional
C_4 favoured
10
20
30
40
Daytime growing-season temperature (°C)



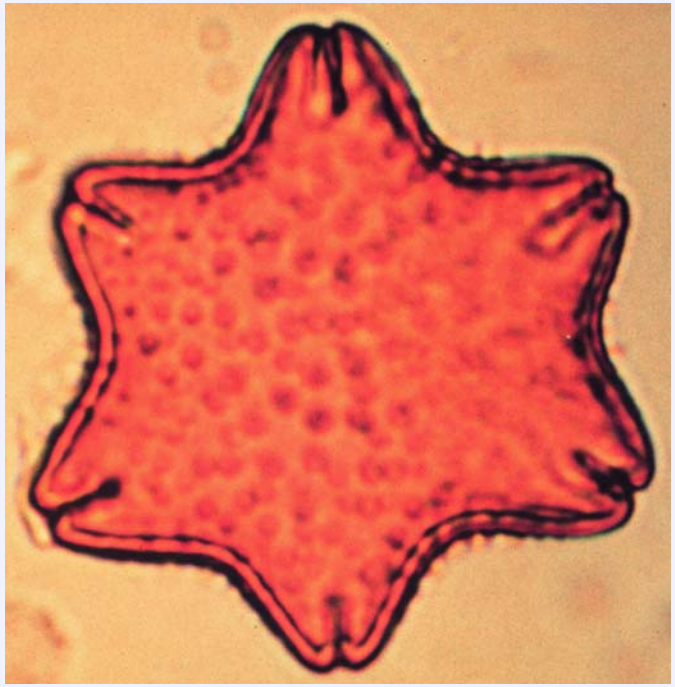

Antarctica today


Antarctica 35 Ma



Cretaceous and Cenozoic plant localities in Antarctica

The Beardmore Glacier

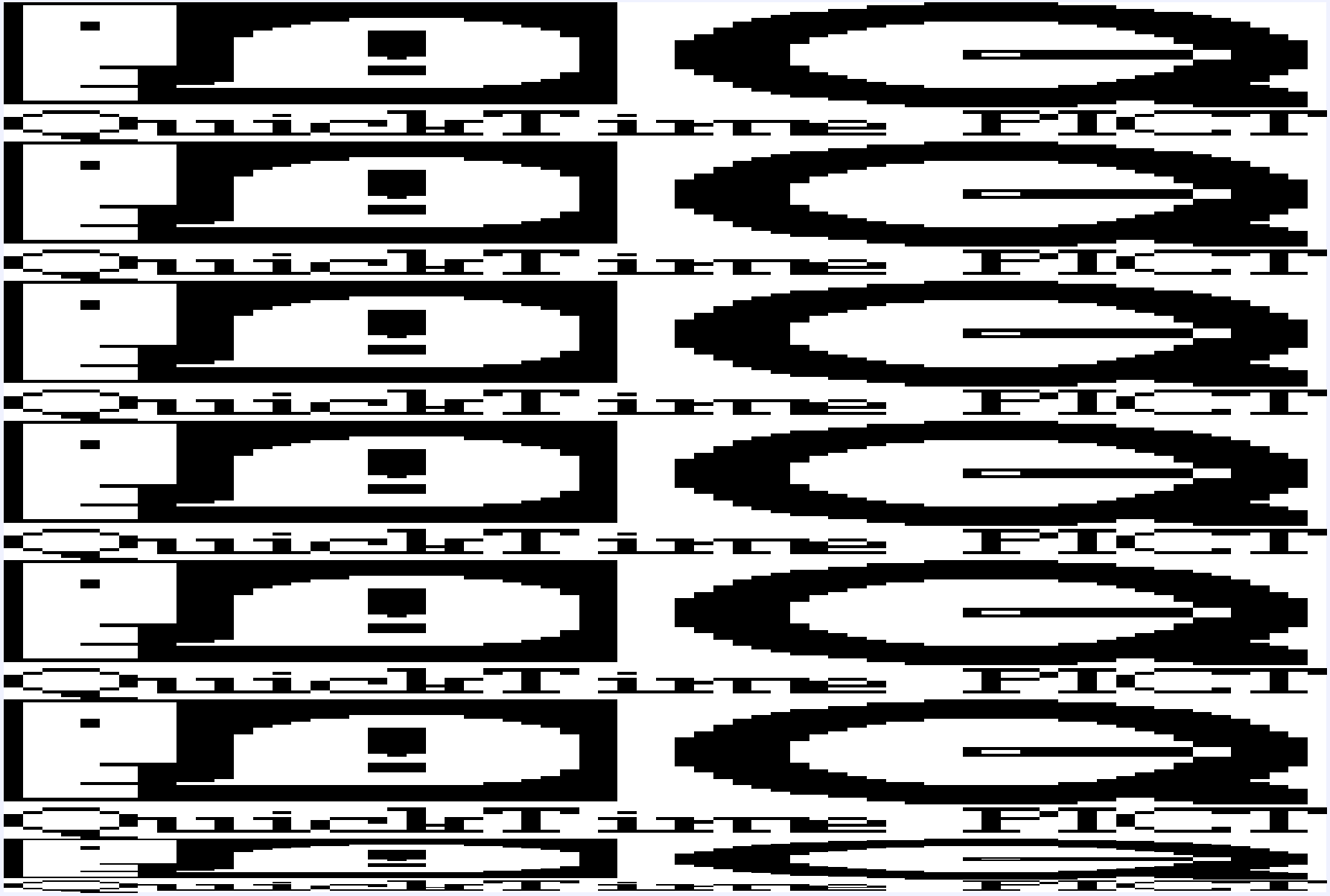


Nothofagus pollen was the first fossil discovered in the Sirius Group sediments. It was presumed that this pollen had been reworked from significantly older sediments

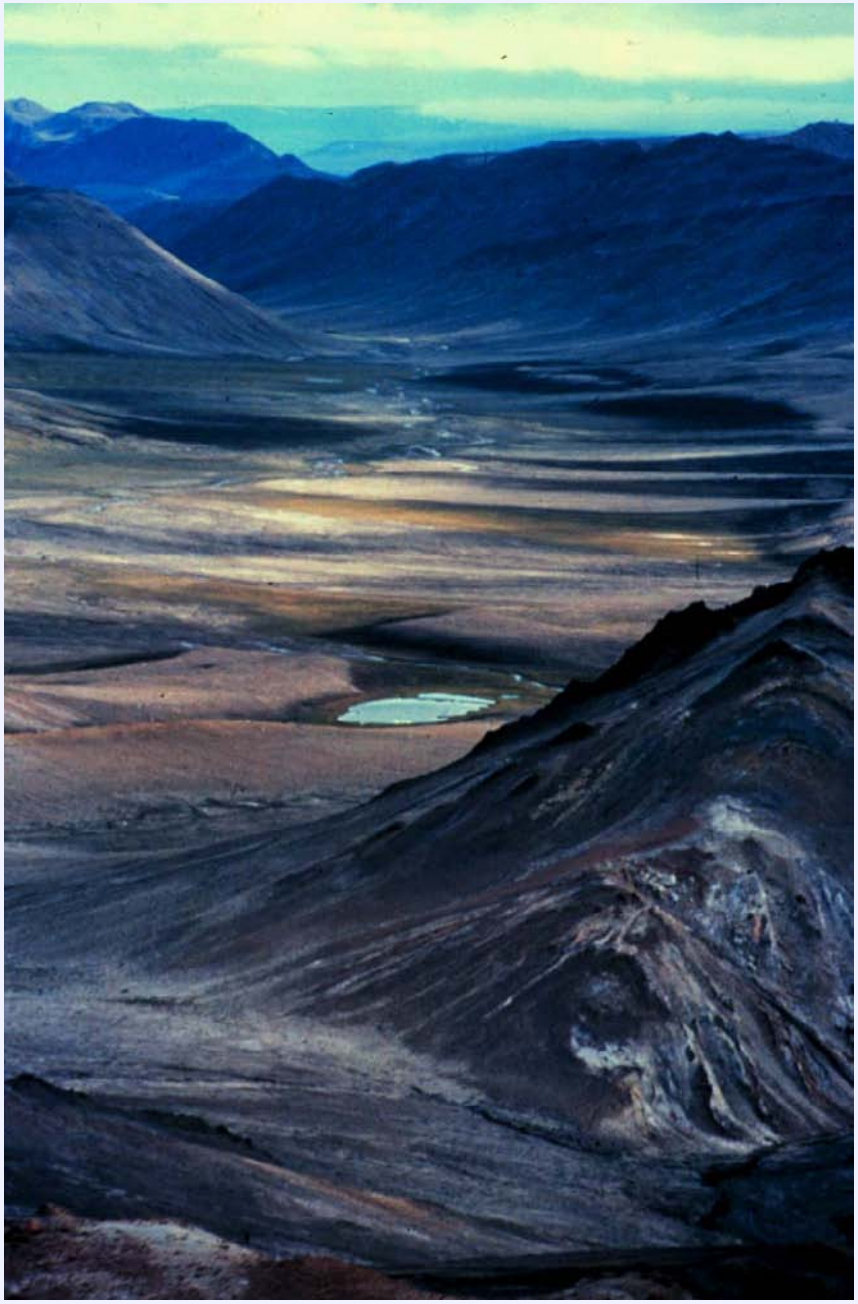
Fossil *Nothofagus* wood was later discovered in the Sirius Group sediments. It was suggested that this wood may also have been reworked.

Finally, a single bed of *Nothofagus* leaves was discovered. These are too fragile to have been reworked.

All stems of *N. beardmorensis* are highly asymmetrical, like the living species on the right and with very small growth rings (<1mm).



Nothofagus gunnii, Australia's only winter deciduous species



Ellesmere Island in the Canadian Arctic - an analogue for Pliocene Antarctica?

Arctic Willow
(*Salix arctica*)

Flowers of
Arctic Willow

Climate estimates based on *Nothofagus* species in the Sirius Group sediments

	Vanda Station	***Sirius**	**Sirius *Nothofagus***
Summer	**+2°C**	**-10°C**	**> +5°C**
Winter	**-36°C**	**-48°C**	**? -22°C**
Mean	**-18°C**	**-28°C**	**-15°C**

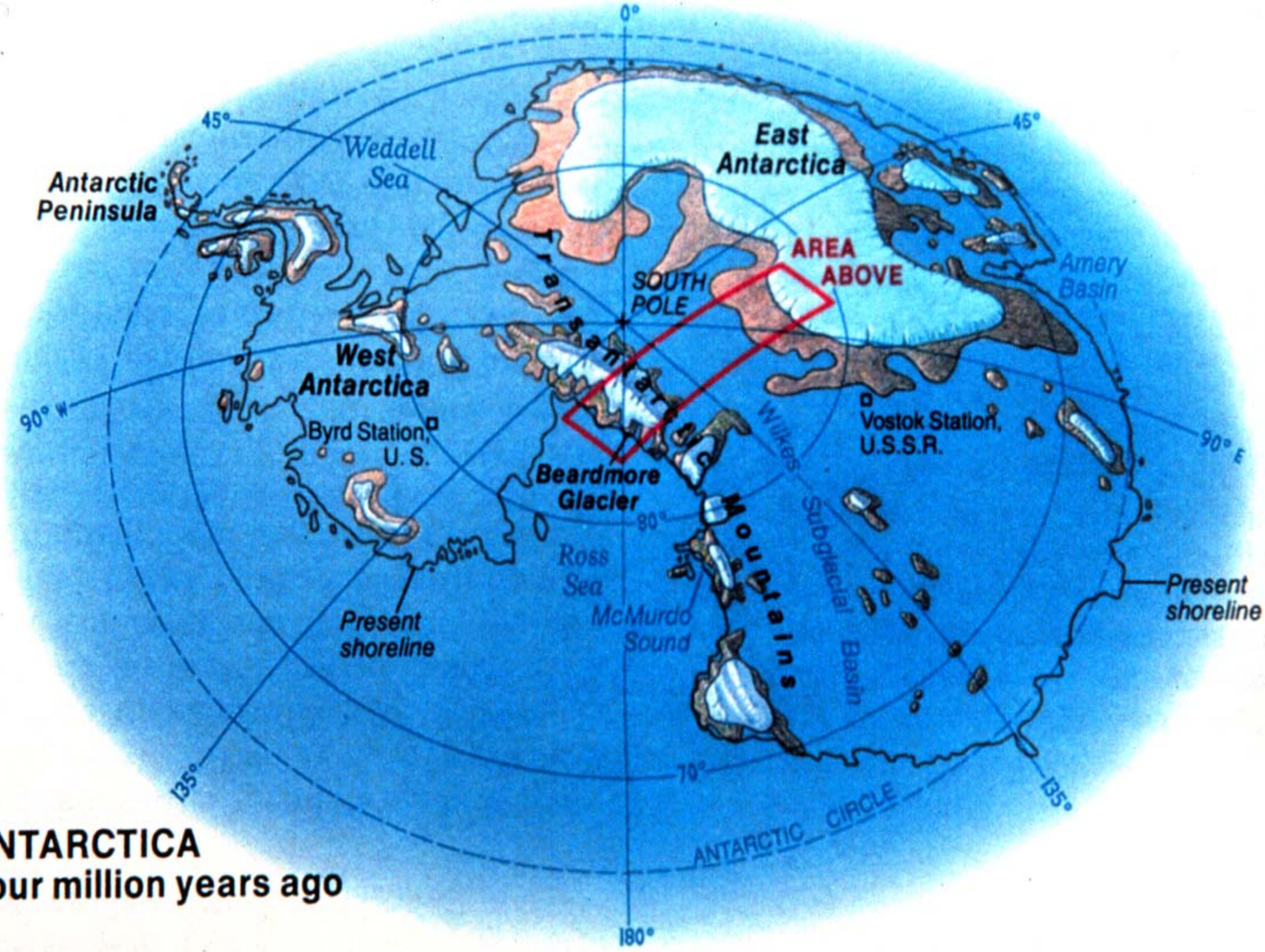
*based on a lapse rate of -0.65°C/100m altitude

ANTARCTICA

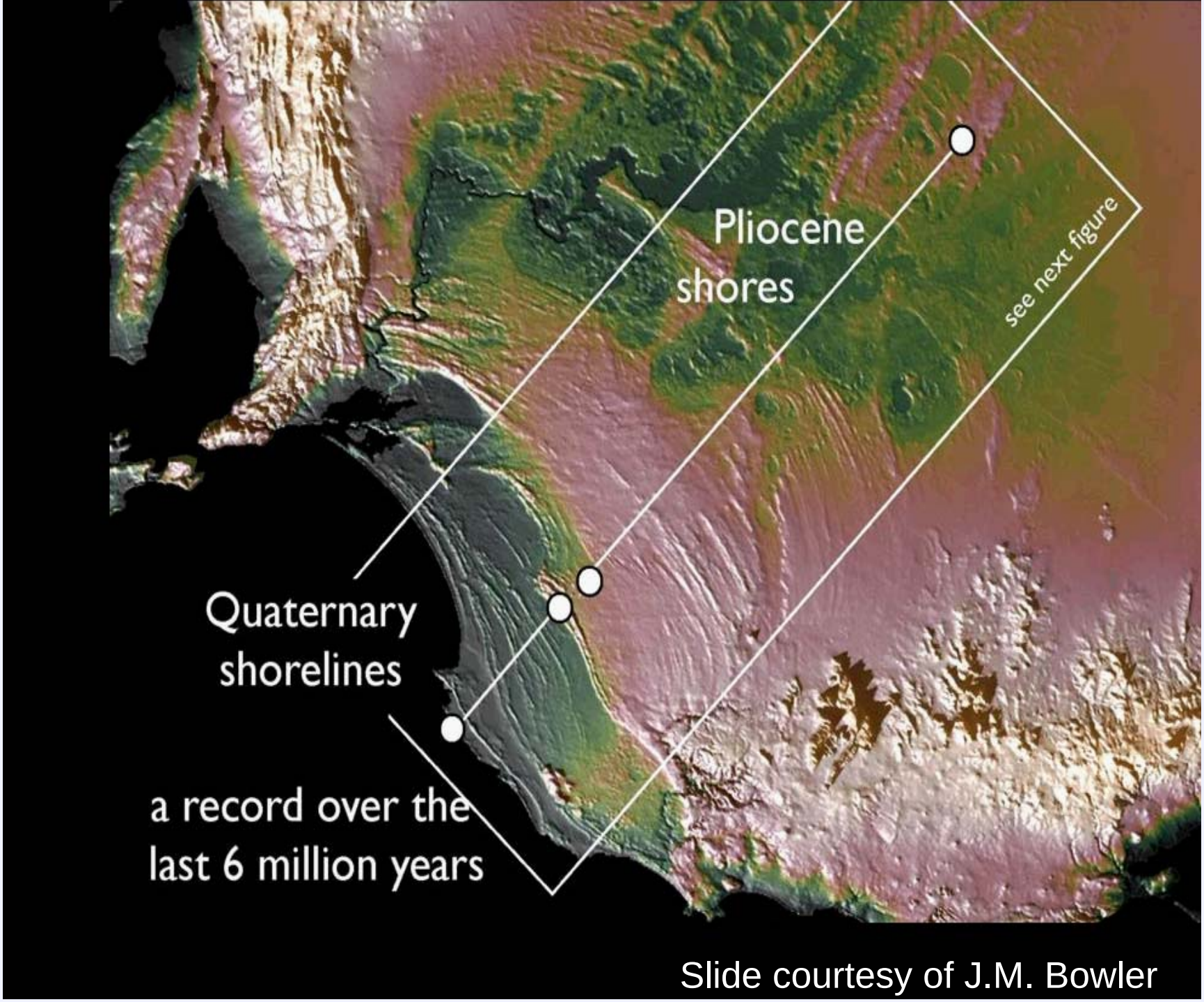
'THE ULTIMATE IN FUTURE HISTORY' *DAILY MAIL*

KIM STANLEY ROBINSON

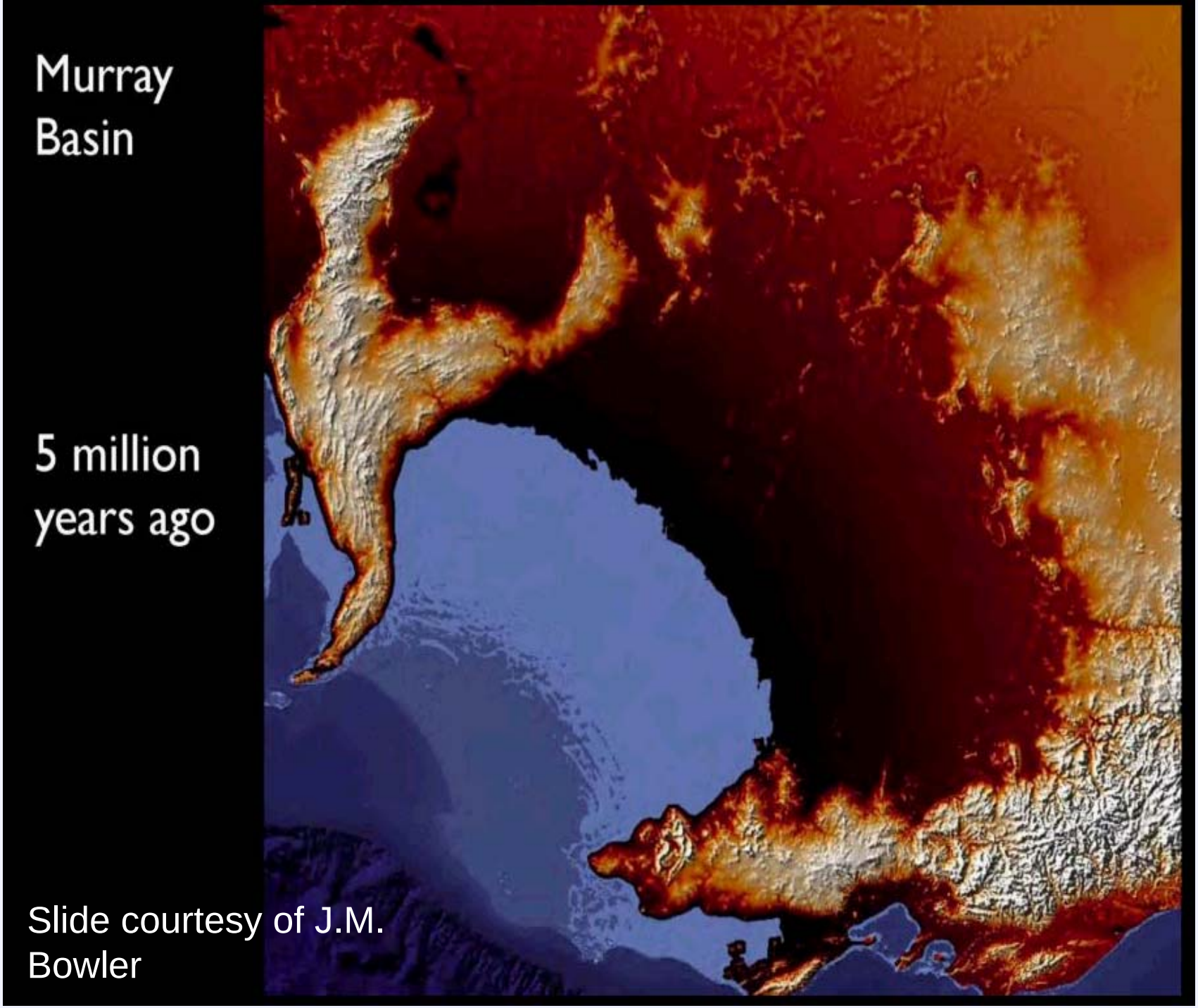
AUTHOR OF THE WORLDWIDE
BESTSELLING MARS TRILOGY



ANTARCTICA
Four million years ago



Slide courtesy of J.M. Bowler



Slide courtesy of J.M. Bowler