



Università di Trieste
Corso di Laurea in Geologia

Anno accademico 2019 - 2020

Geologia Marina

Parte V

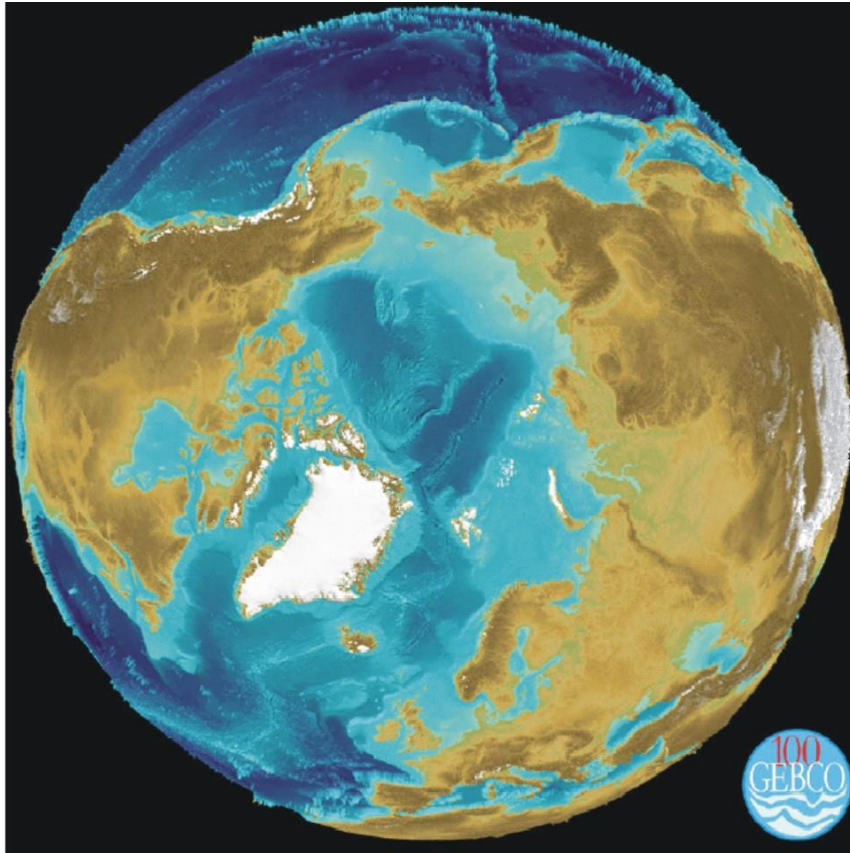
Modulo 5.4 Geologia marina delle aree polari

Docente
Laura De Santis

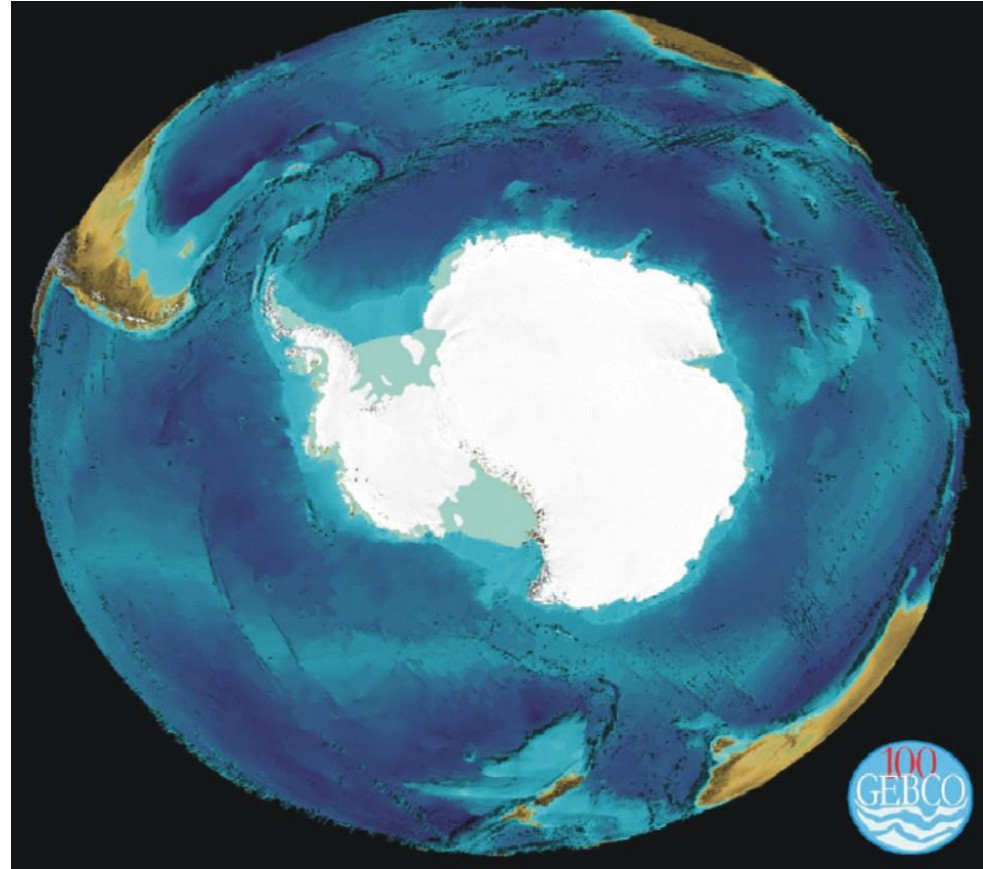


ARGOMENTI

- **Gondwana fragmentation and geological evolution.**
- **Oceanic gateways formation and climate evolution.**
- **The Cenozoic evolution**

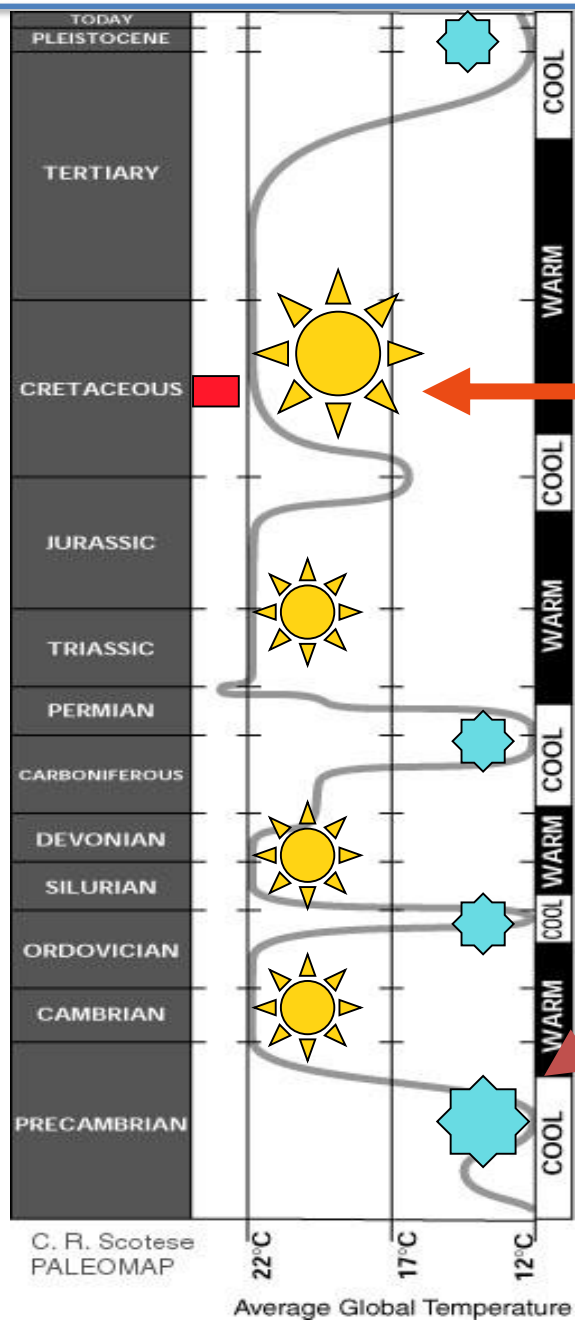


CALOTTA ARTICA



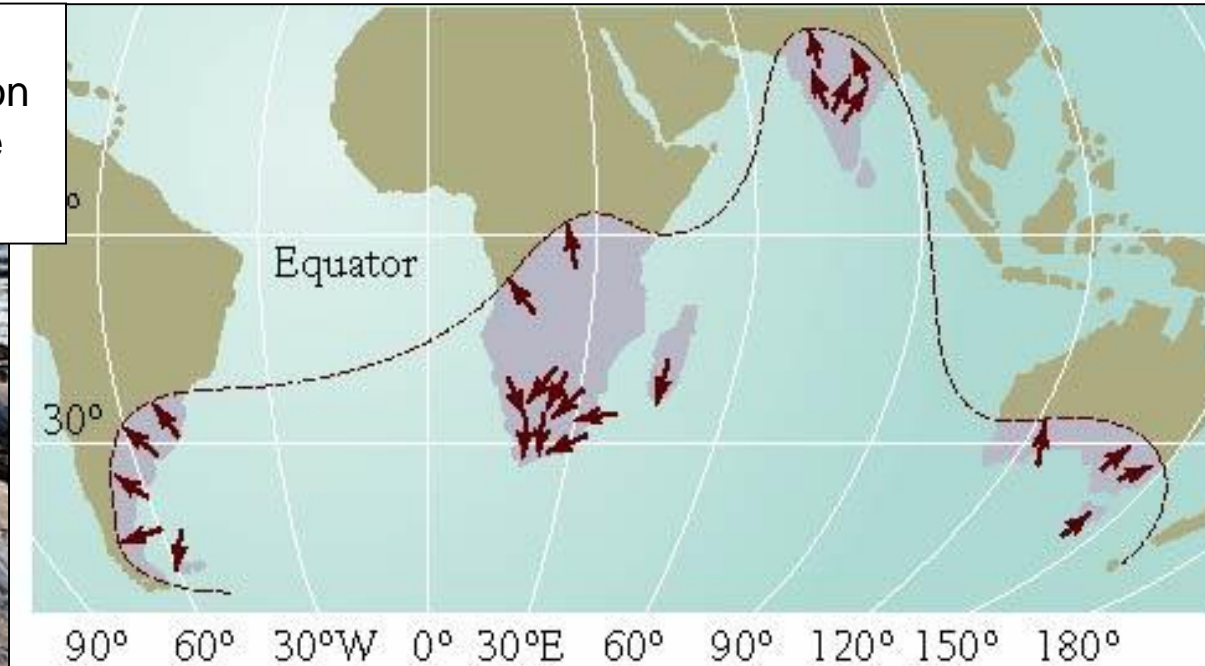
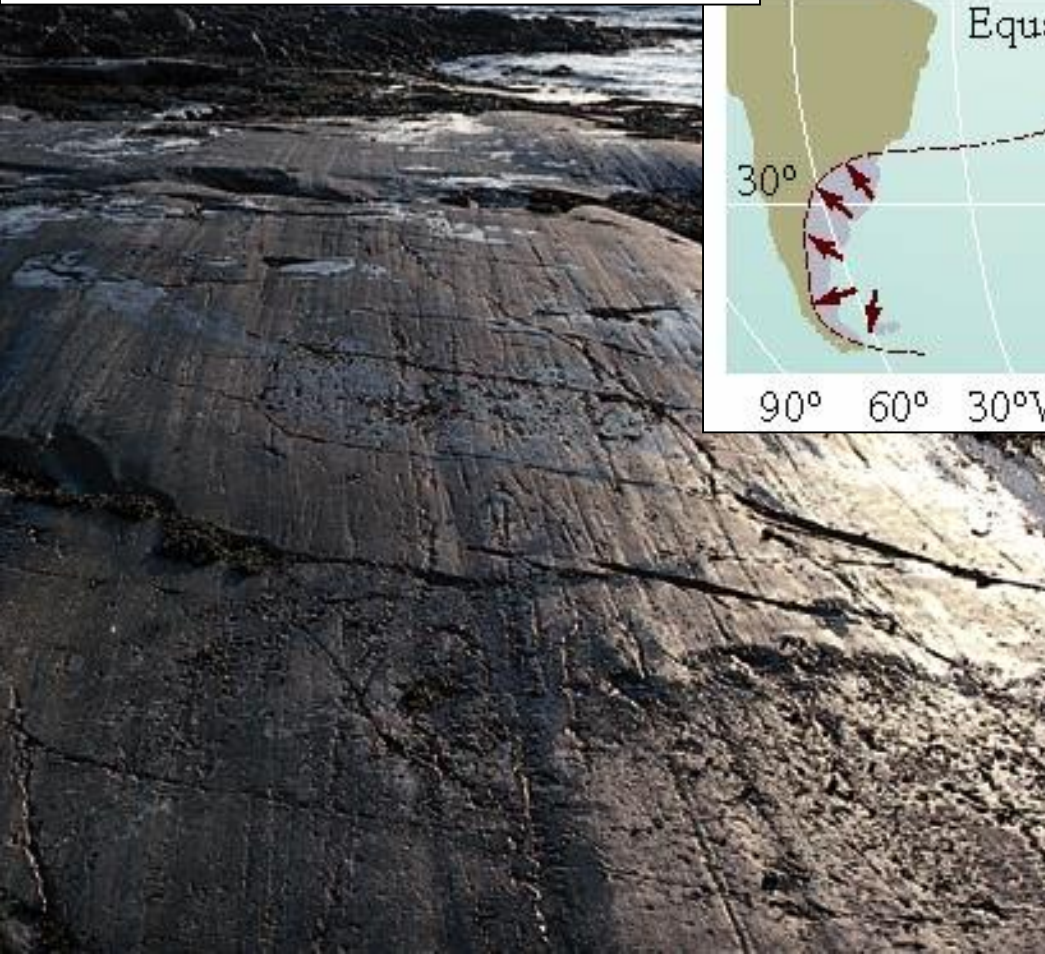
CALOTTA ANTARTICA

Extreme climates throughout the geological time



Evidence of Continental Drift

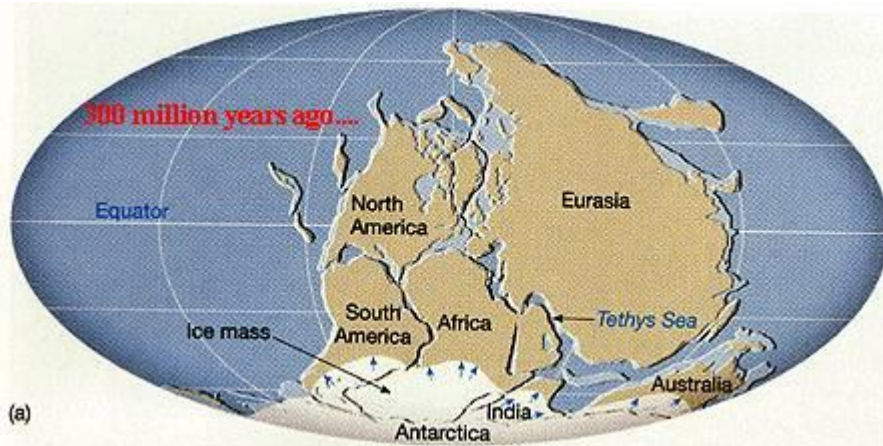
- **Stratigraphic Evidence:**
Orientation of glacial markings on all continents suggest they were linked



La glaciazione Permo-Carbonifera ha determinato lo sviluppo di una calotta glaciale che ha lasciato tracce in Antartide, Australia, India, sud Africa e sud America.

La storia dell'Antartide nel supercontinente Gondwana è lunga e variegata. Dopo la completa amalgamazione di Gondwana (circa 500 milioni di anni fa), l'Antartide, si è trovata in posizione polare in epoca Carbonifero-Permiana, ciò ha determinato una glaciazione che ha portato allo sviluppo di una calotta glaciale più grande di quella che copre l'Antartide attualmente, le cui tracce, in termini di modellamento e depositi glaciali, sono presenti oltre che in Antartide anche in Australia, sud America, Africa, India.

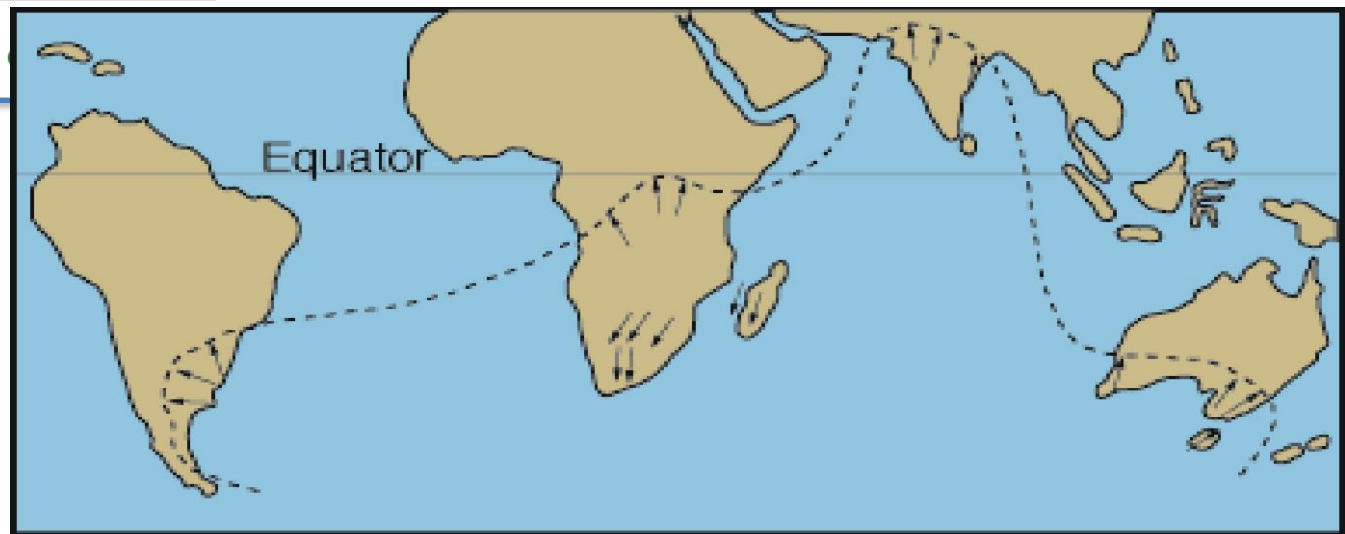
Evidence of Continental Drift



- **Geographic Evidence**

- that even a child can see.
- The continents match up like a puzzle.
- Side note: There have actually been several cycles of supercontinent assembly and disassembly reconstructing pre-Pangea puzzles is a challenge.

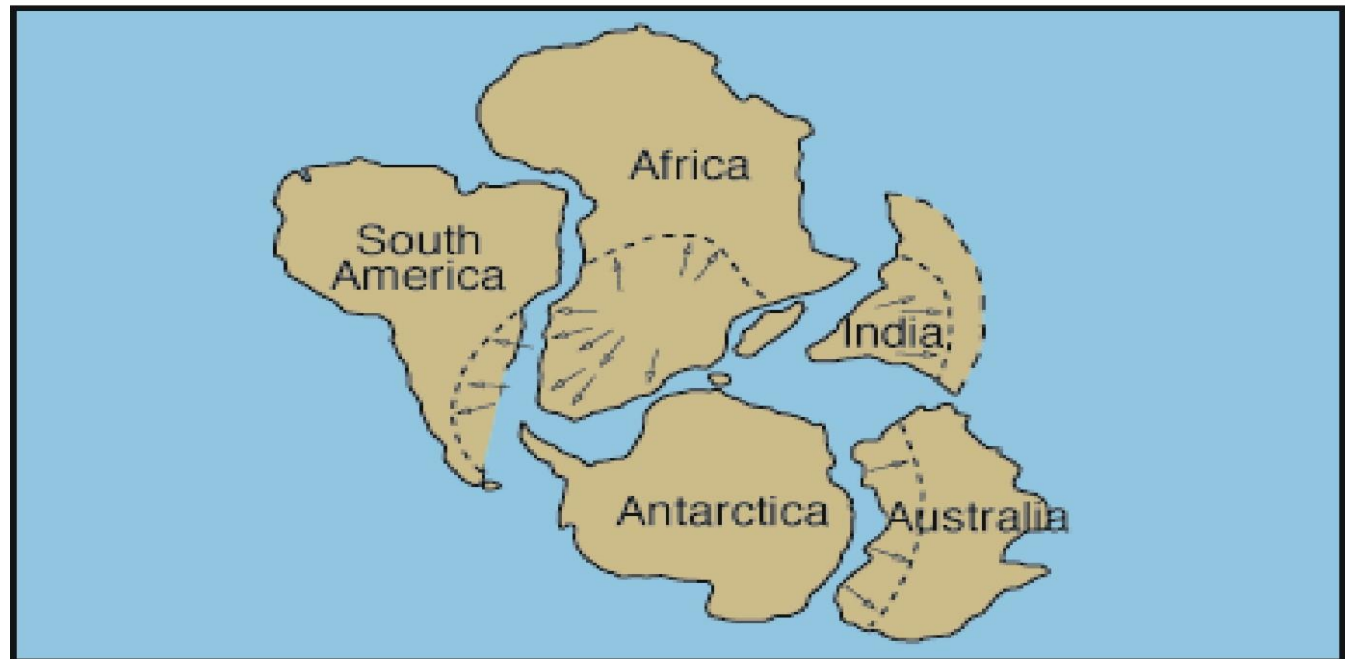
Evidence of continental Drift: Glacial Evidence



Grooves carved by glaciers (shown by arrows) provided evidence for continental drift. This diagram assumes the continents were in their present-day locations.

Large ice masses carve grooves in the rocks over which flow.

Such masses tend to flow outward (generally downhill) from a central locality



The distribution of glacial features can be best explained if the continents were part of Pangaea.

Successivamente (tardo Permiano) Gondwana iniziò a migrare verso latitudini intermedie ed il clima divenne progressivamente più mite:



Foglie fossili di Glossopteris presenti in tutto il Gondwana dopo la glaciazione Permiana. Foto: P. Barrett.



Tronco fossile di Glossopteris nelle Arenarie di Beacon della Terra Vittoria settentrionale (età Permo-Triassica), che testimonia la presenza in Antartide di foreste di conifere dopo la glaciazione Permo-Carbonifera. Foto: C. A. Ricci.



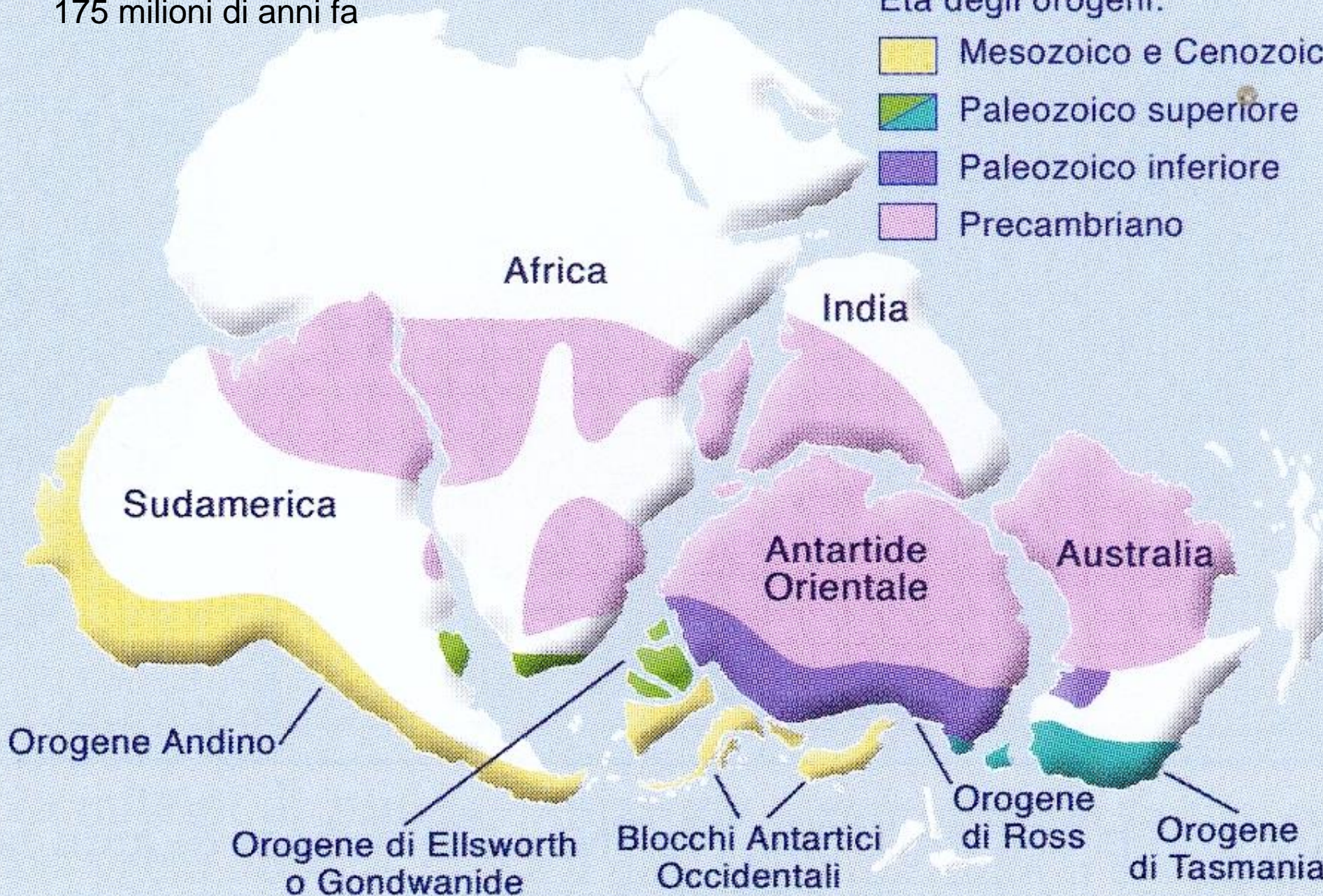
Ricostruzione dello scheletro di Lystrosaurus, un rettile erbivoro alto circa un metro e lungo quasi due metri che in grandi mandrie abitava varie regioni del supercontinente Gondwana durante il Trias ed aveva scarse capacità natatorie. Foto: P. Barrett.

ricostruzione del supercontinente Gondwana

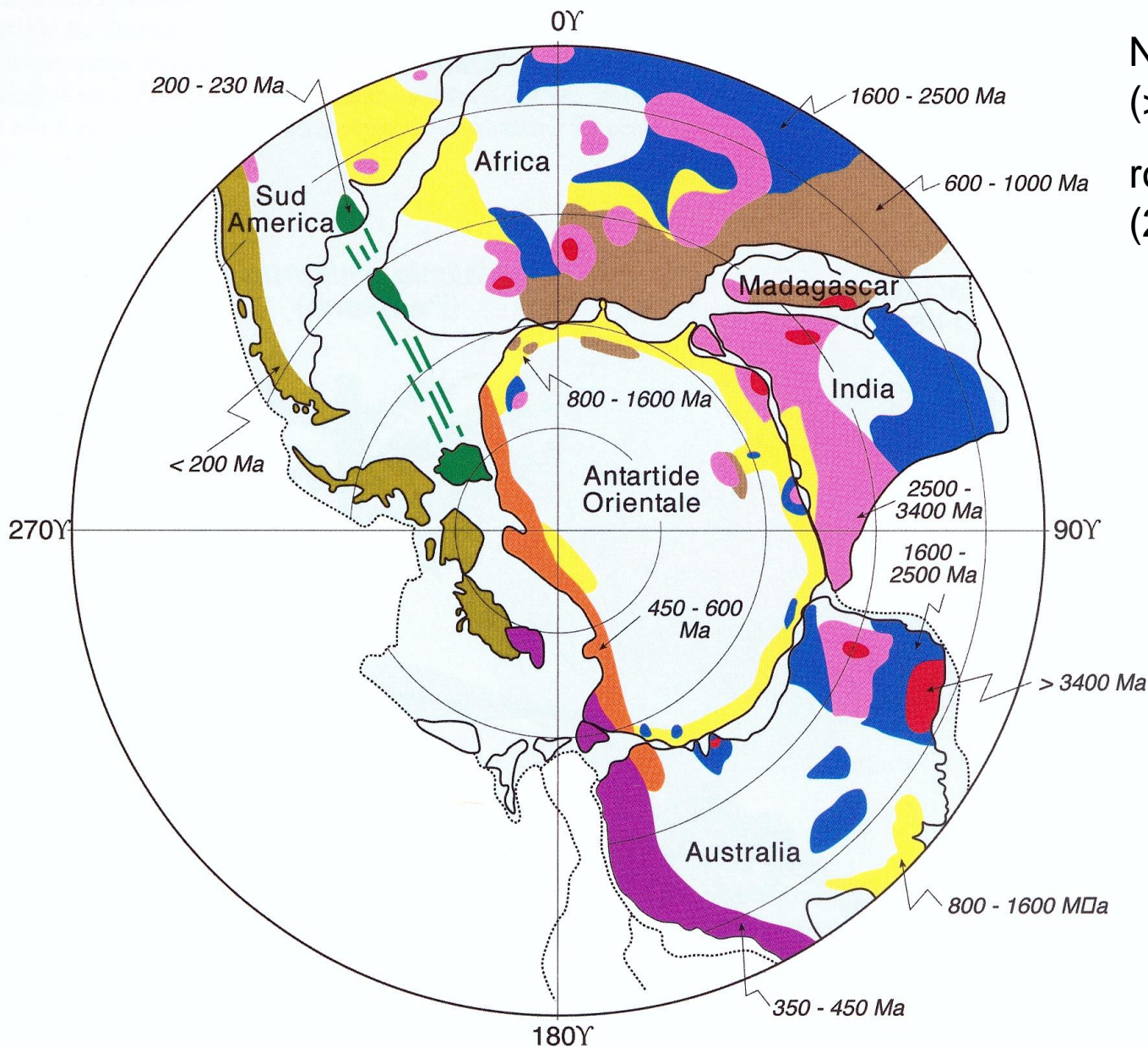
175 milioni di anni fa

Età degli orogeni:

- Mesozoico e Cenozoico
- Paleozoico superiore
- Paleozoico inferiore
- Precambriano



Il supercontinente Gondwana è esistito fra 500 e 150 milioni di anni



Nuclei archeani
(>2500 Ma)

rocce proterozoiche
(2500-600 Ma);

Fasce orogeniche
di Ross (450-600
Ma),

Fasce orogeniche
di Ellsworth (200-
230 Ma)

Fasce orogenica
Andina (200-65
Ma).

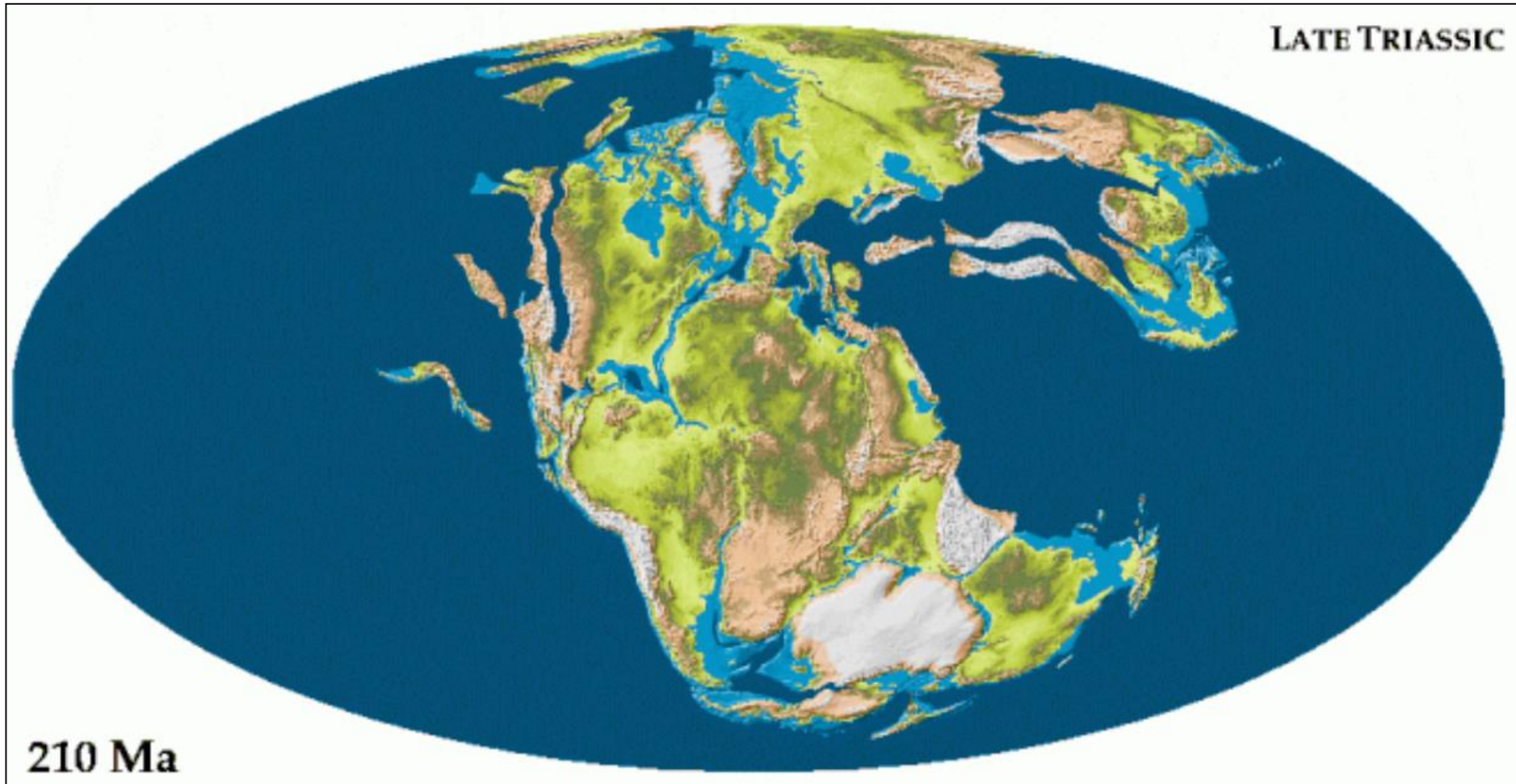
Il supercontinente Gondwana è esistito fra 500 e 150 milioni di anni fa.

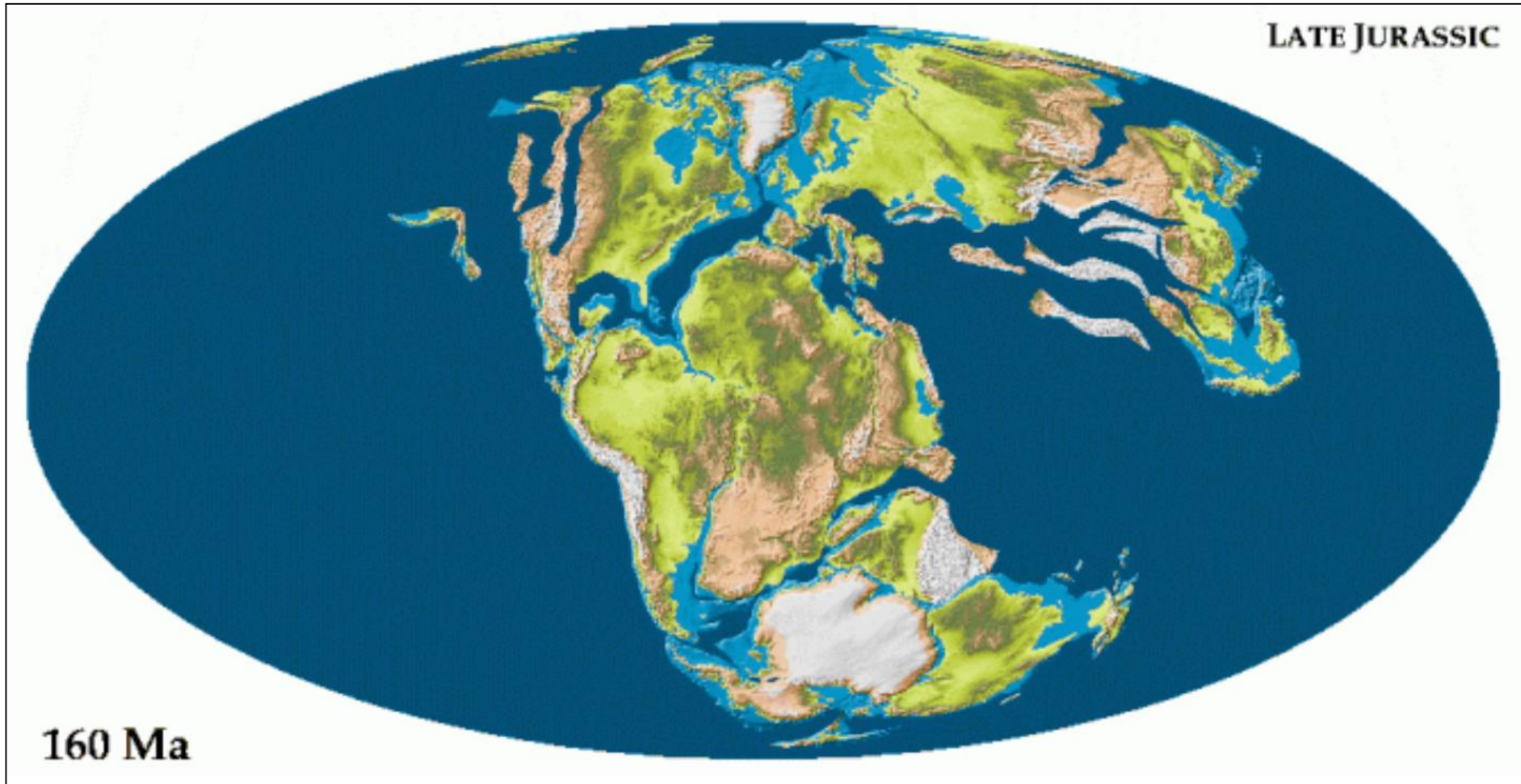
La sua ricostruzione è basata sulle corrispondenze morfologiche e dalla comune storia geologica documentata dalle rocce che sono presenti nei vari continenti.

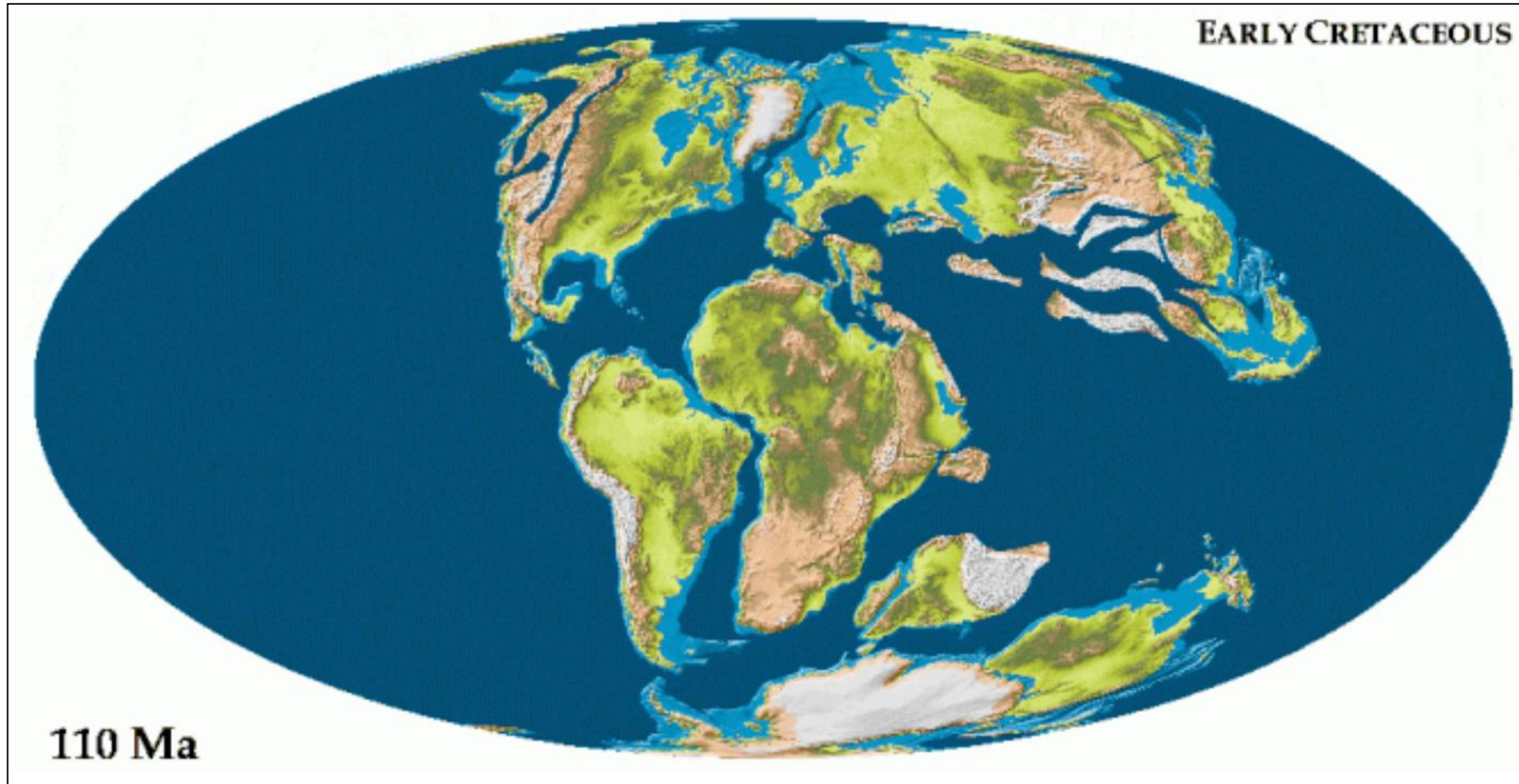
La figura precedente evidenzia in modo schematico i nuclei archeani (>2500 Ma) e quelli proterozoici (2500-600 Ma); le fasce orogeniche di Ross (450-600 Ma), di Ellsworth (200-230 Ma) ed Andina (200-65 Ma). La ricostruzione colloca l'Antartide orientale al Polo Sud attuale.

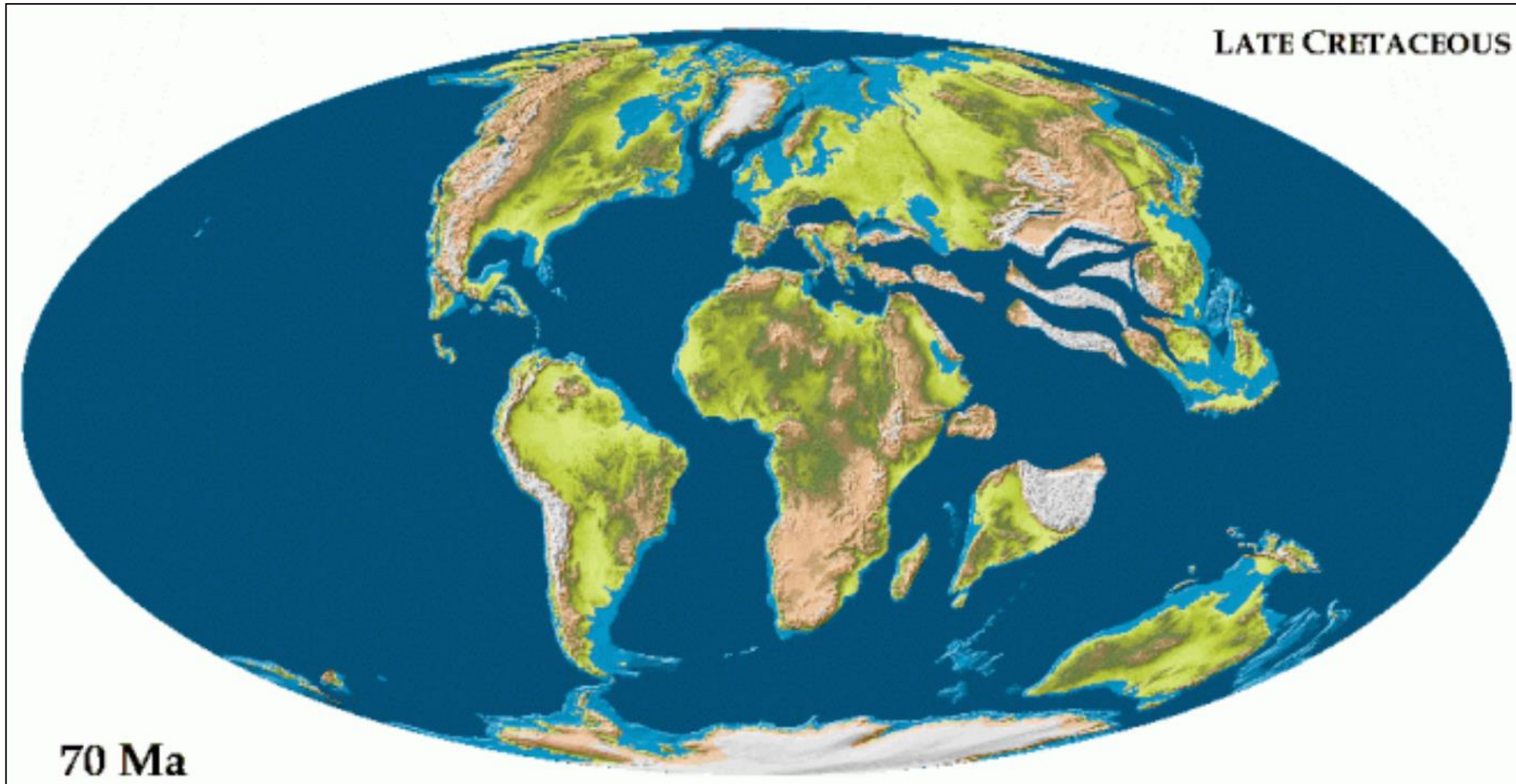
Nel tardo Permiano il Gondwana iniziò a migrare verso latitudini intermedie ed il clima divenne progressivamente più mite: cominciarono a svilupparsi delle grandi foreste a *Glossopteris*, una flora decidua, esclusiva dell'emisfero meridionale, che è testimoniata dalla presenza di foglie e tronchi fossili in rocce sedimentarie di età Permo-Triassica.

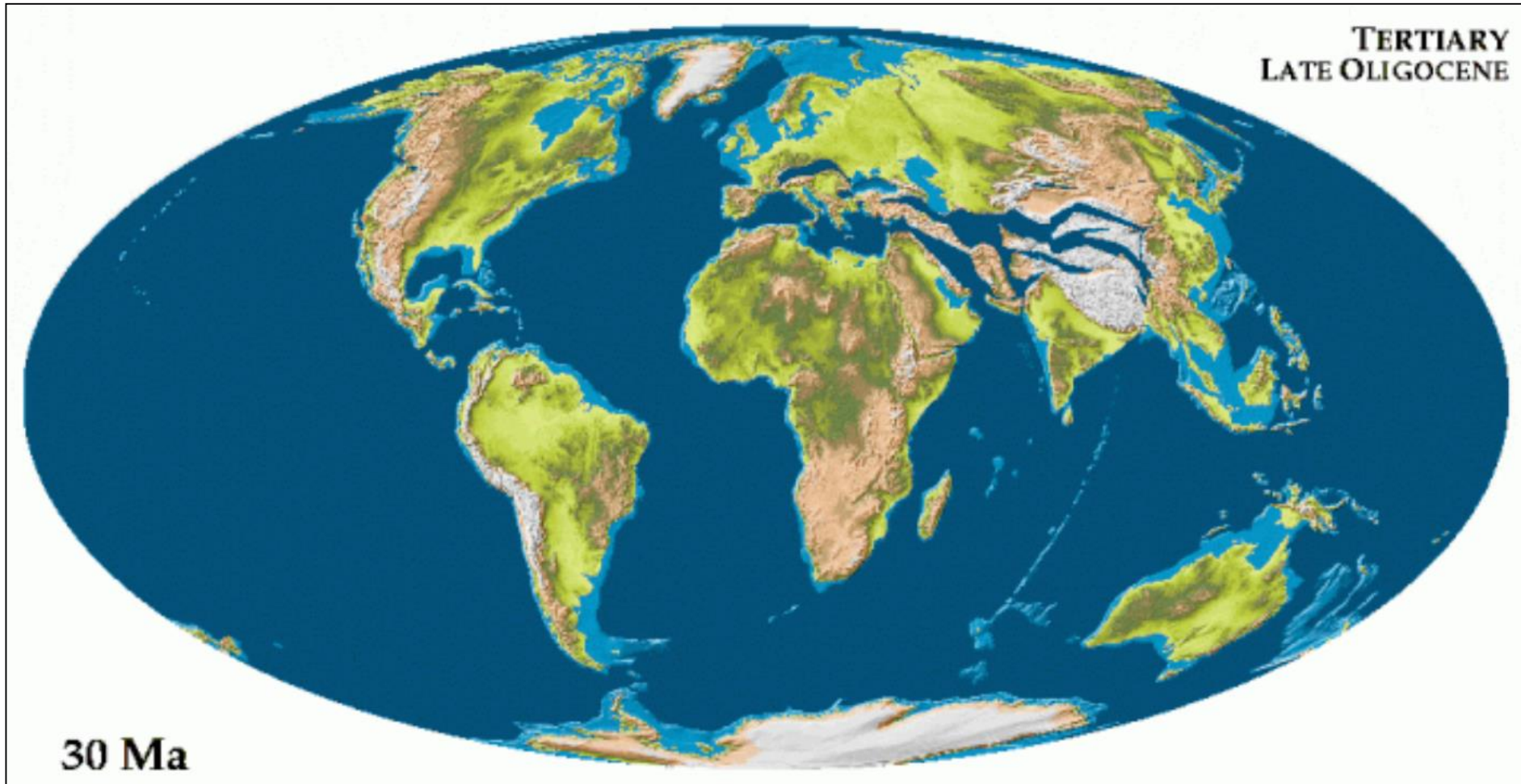
Nel Trias un rettile erbivoro noto come *Lystrosaurus*, vive in Australia, sud America, India oltre che in Antartide. Tenendo presente le scarse capacità natatorie su lunghe distanze di tale rettile e che quindi questi poteva spostarsi da un punto all'altro dei vari continenti solo attraverso la terra ferma, la contemporanea presenza del listrosauro in queste differenti regioni, è un importante prova a sostegno dell'esistenza di un unico continente, nell'intervallo di tempo tra il Carbonifero e il Giurassico.

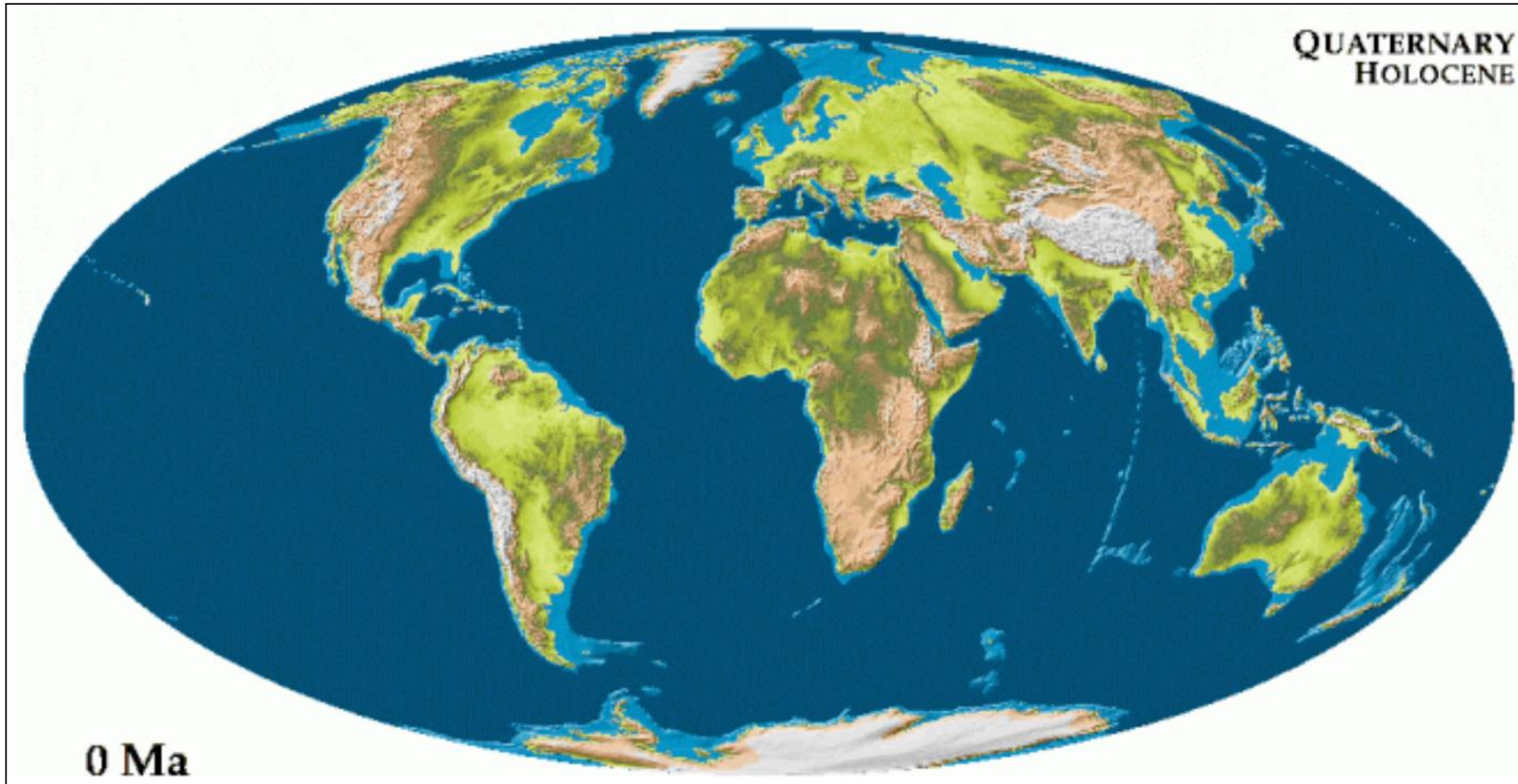












Catena Transantartica

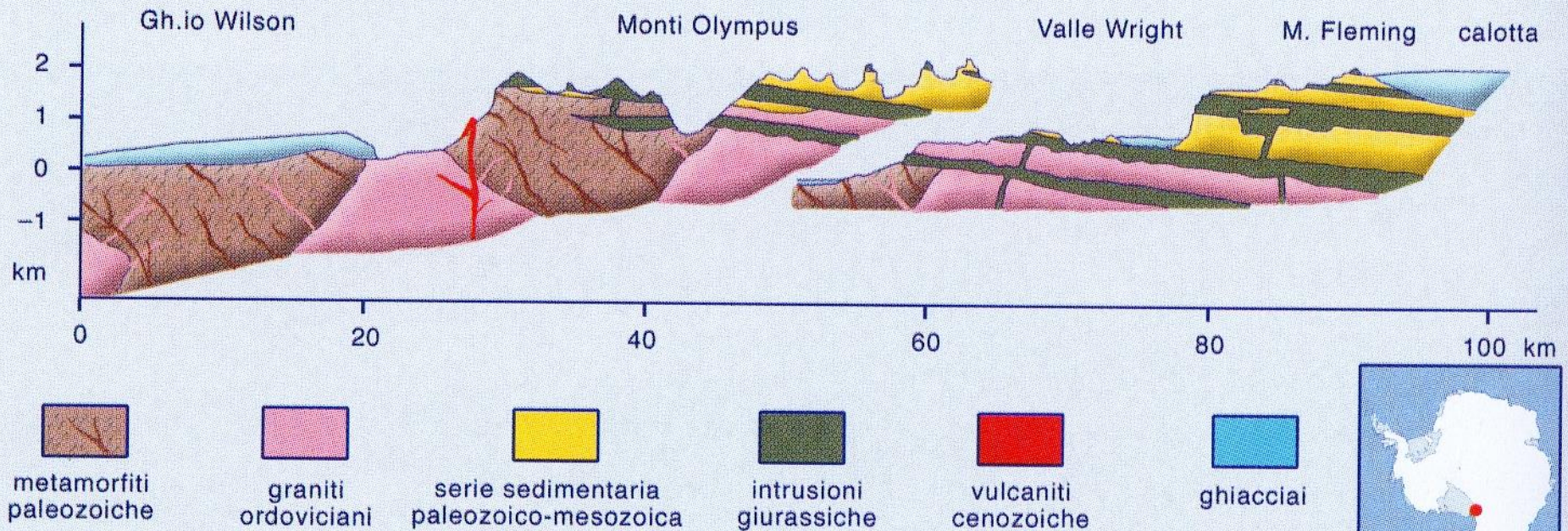
Arenarie del Beacon (tardo Paleozoico, *Devoniano* – Mesozoico, *Triassico*)
Doleriti del Ferrar (lave giurassiche)



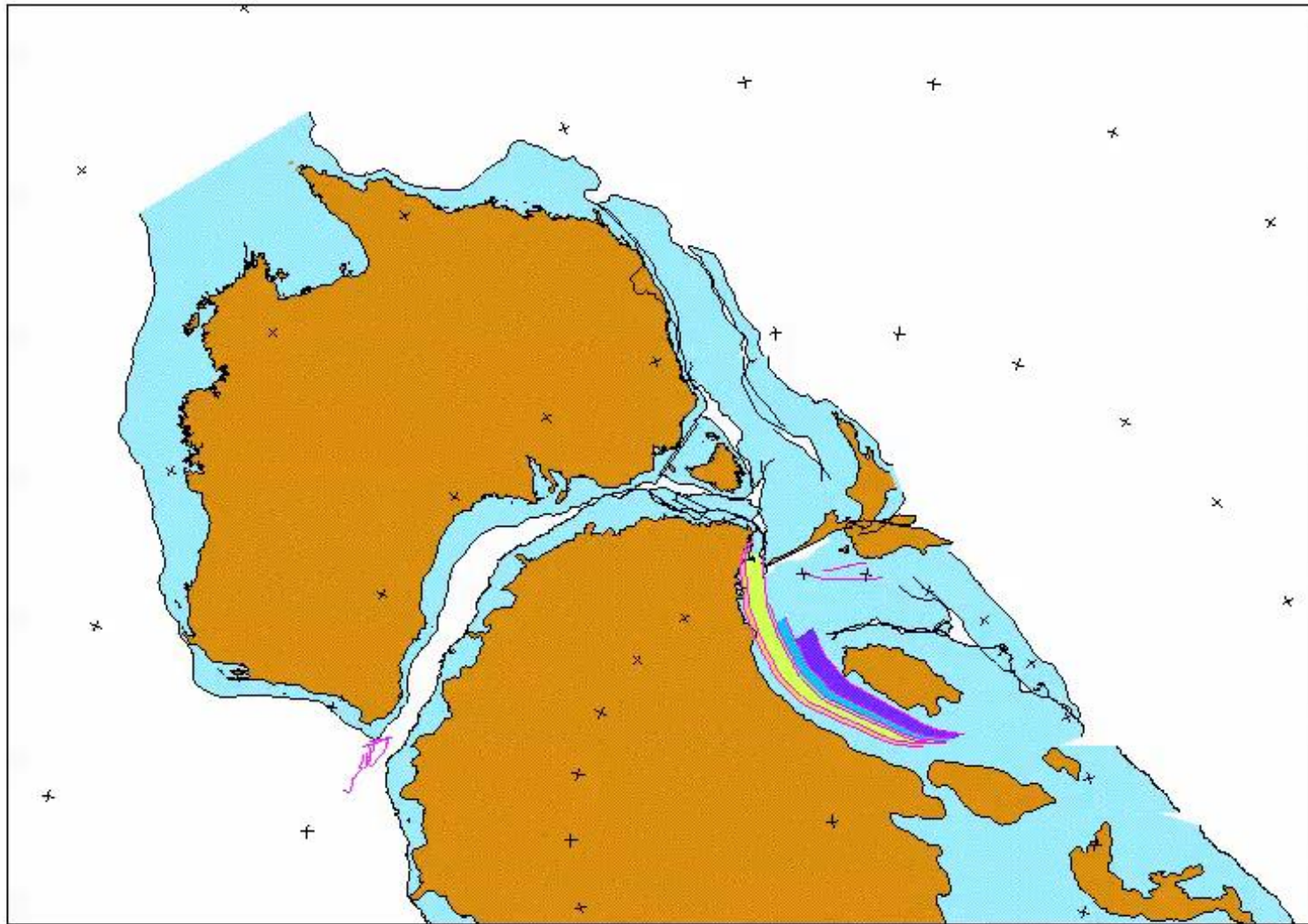
Foto: L. De Santis

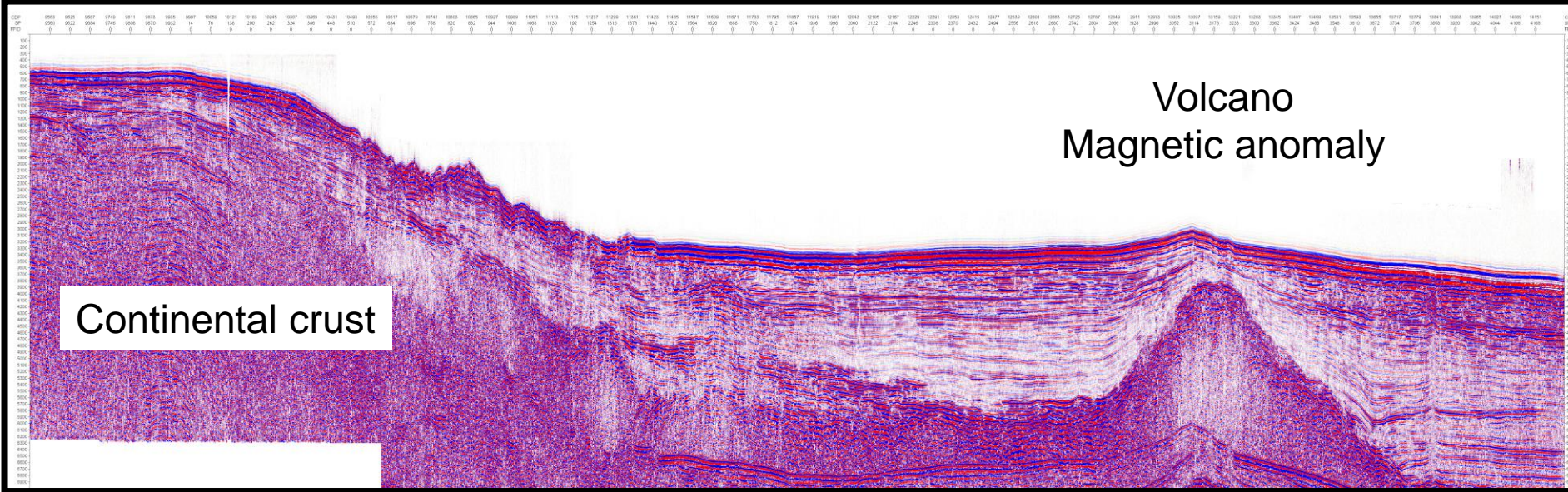
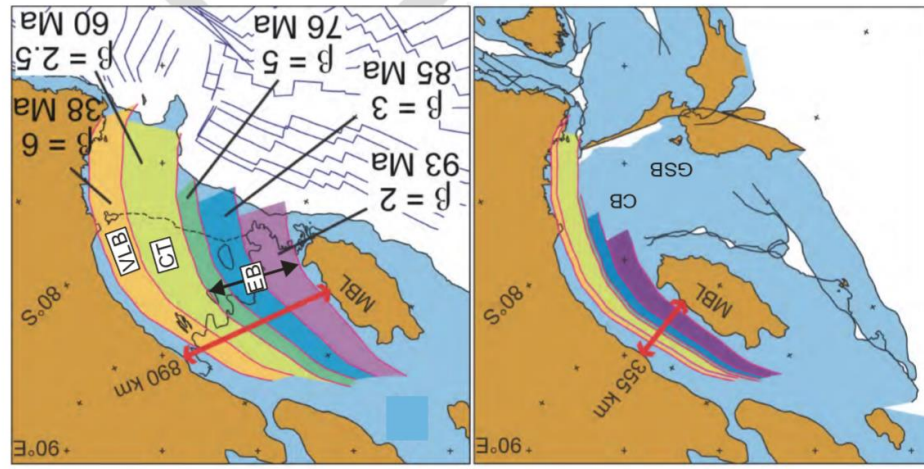
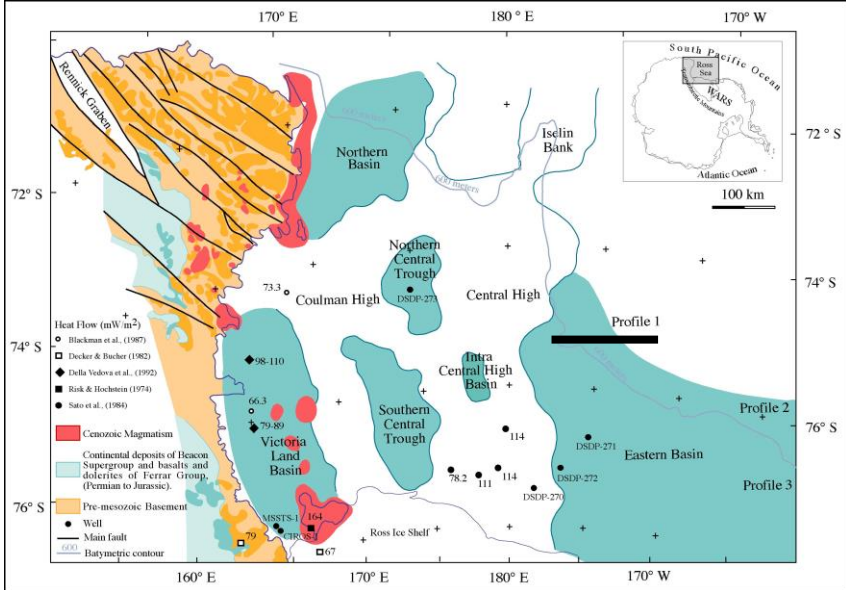


sezione geologica attraverso le Valli Secche di McMurdo



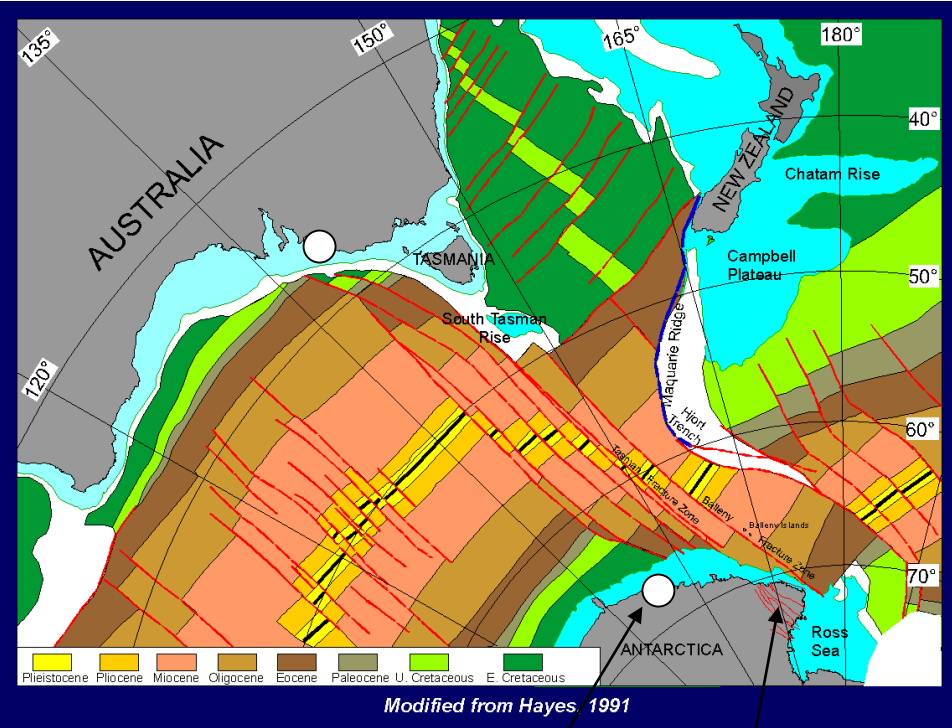
105.0 Ma



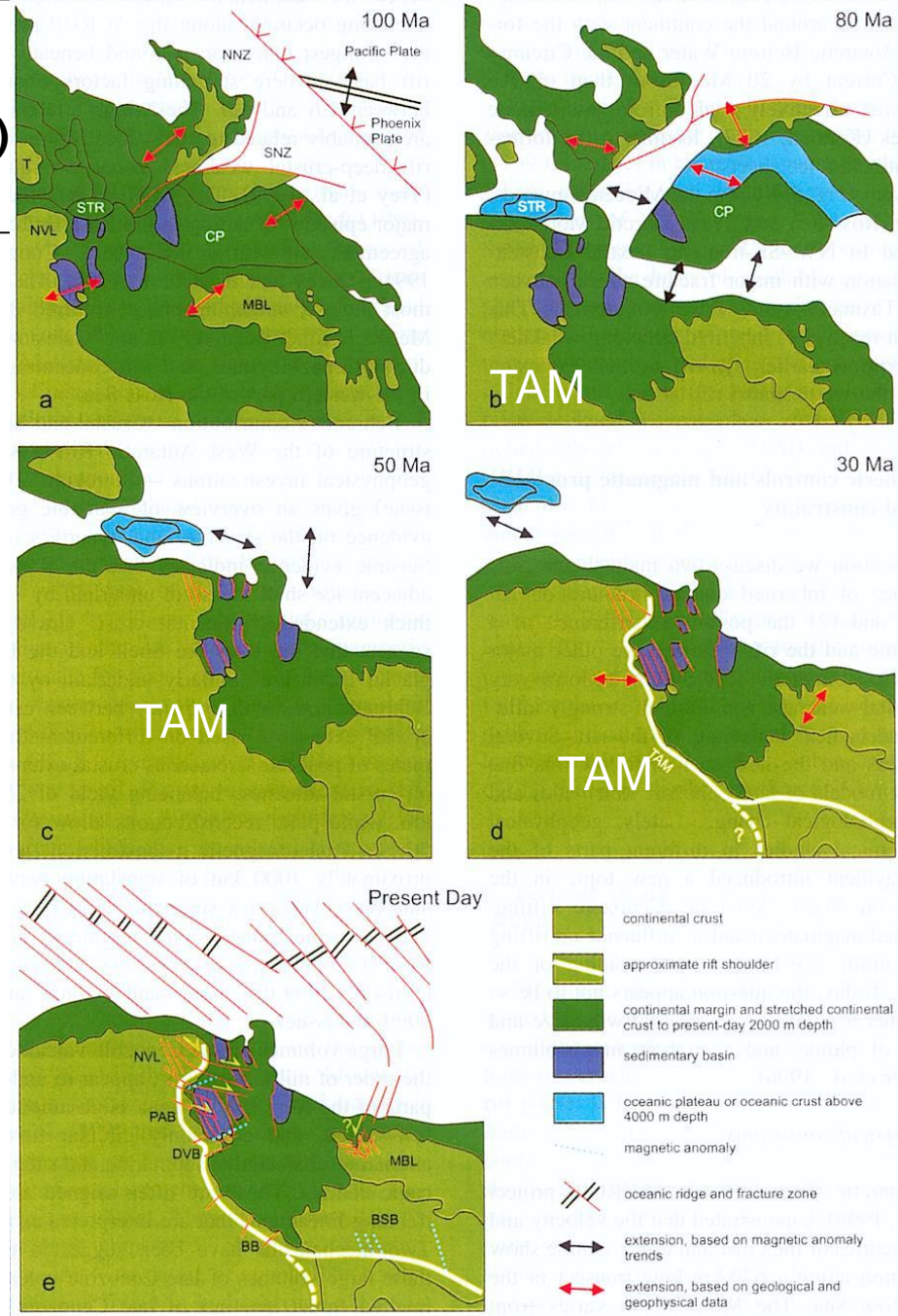


Profilo MAGE02

Break-up tra:
Australia e Antartide (83 Ma)
Mare di Ross Orient. e Campbell Plateau (84 Ma)
Mare di Ross Occ. e Tasmania (50 Ma)

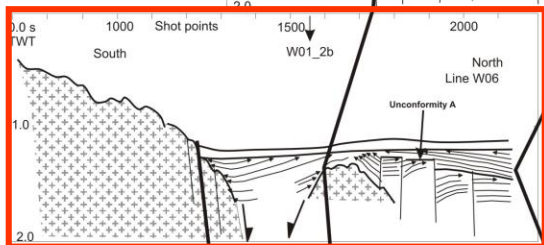
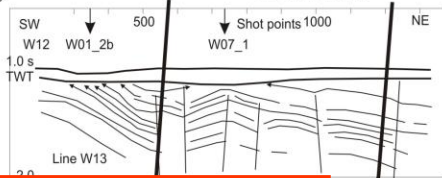
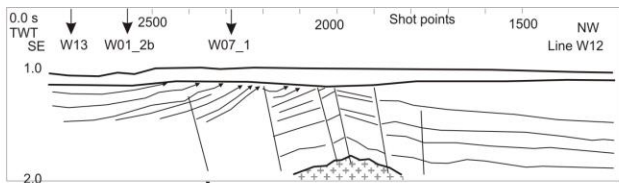


George V Land
 Victoria Land



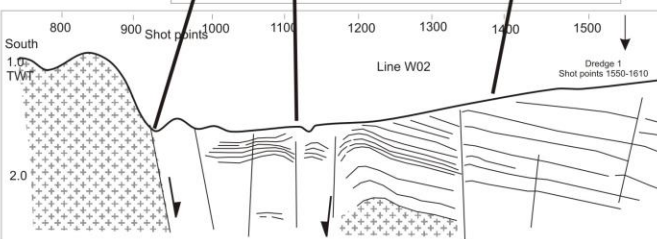
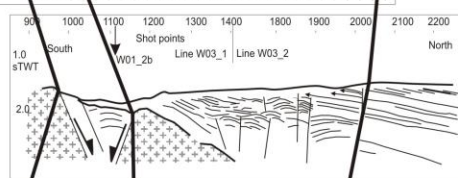
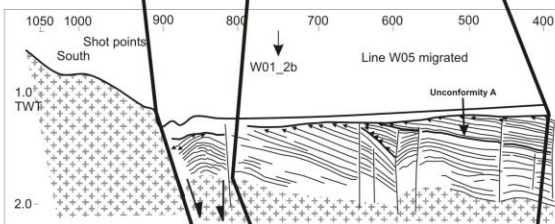


West

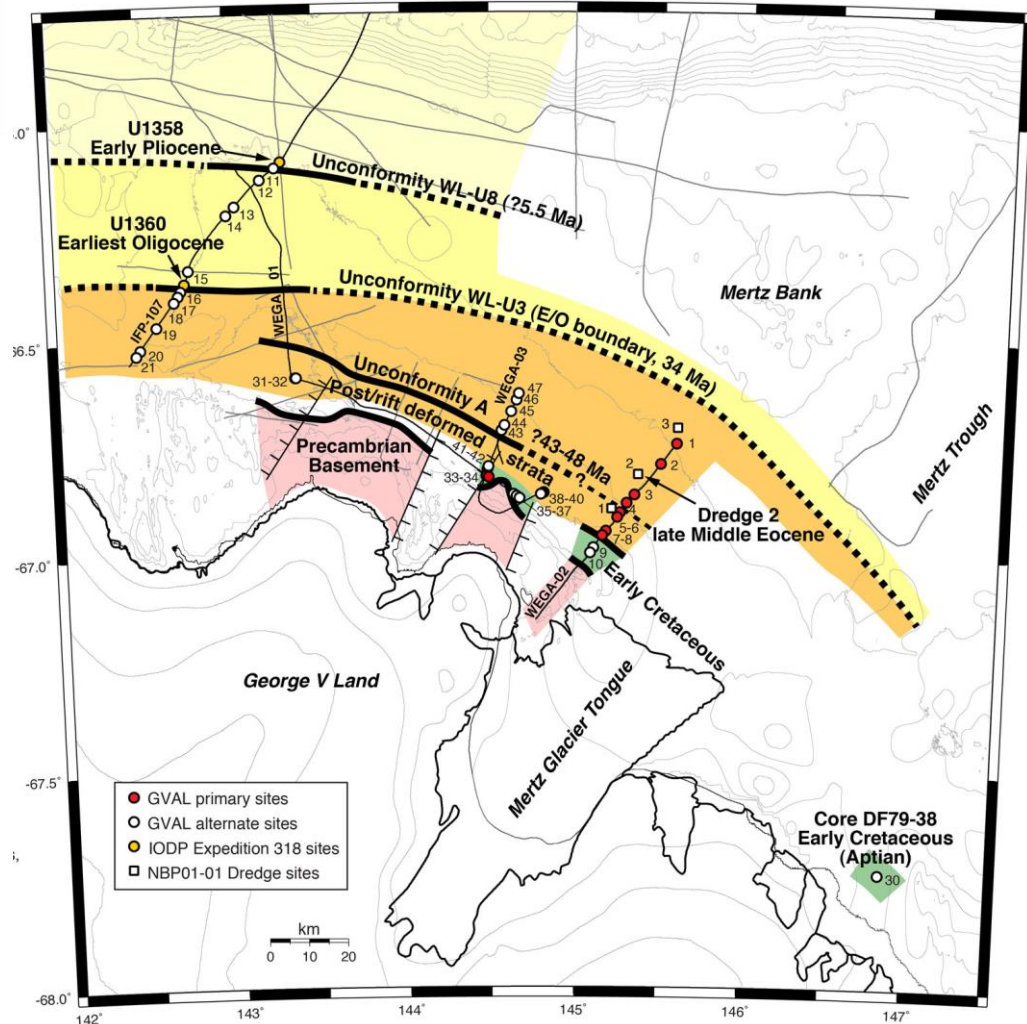


2.5 km

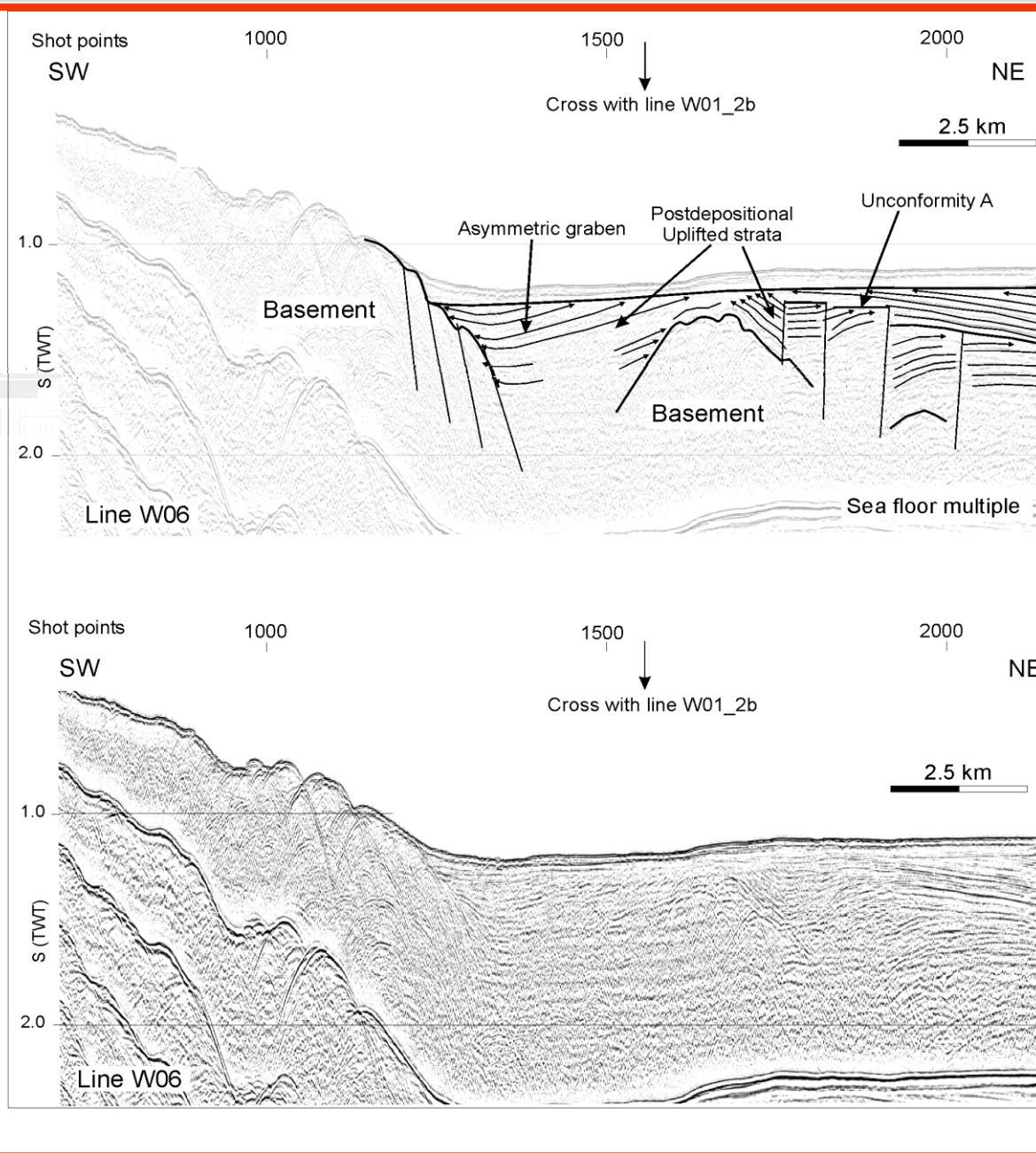
Rifted Basement Rifted graben uplifted during post-rift Post-rift Flower structures TECTONIC PROVINCES



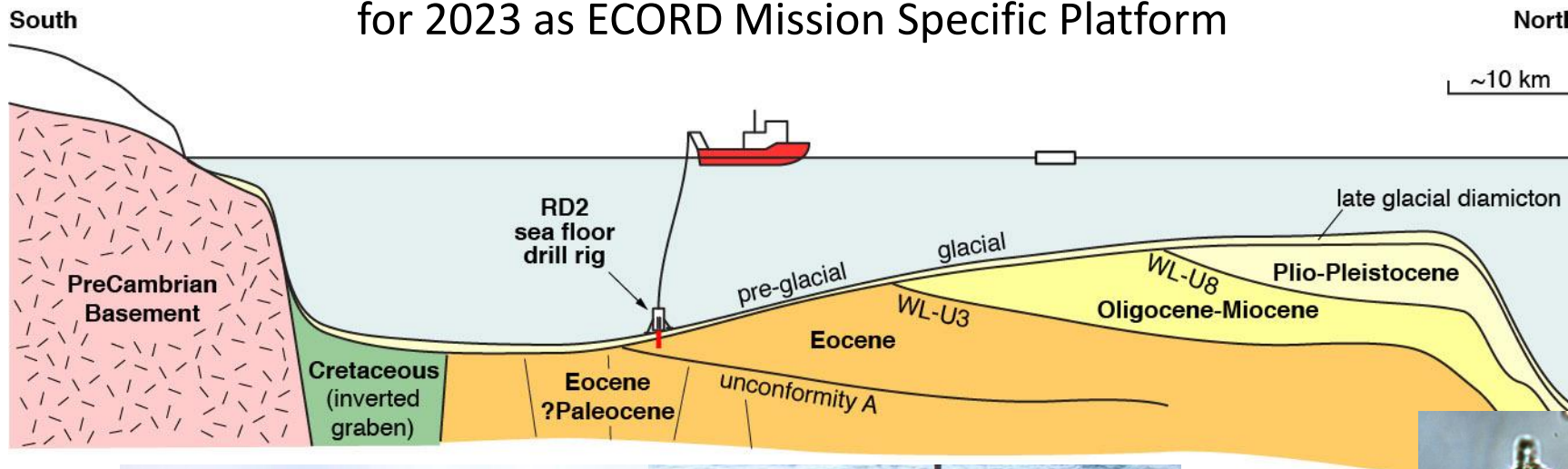
East



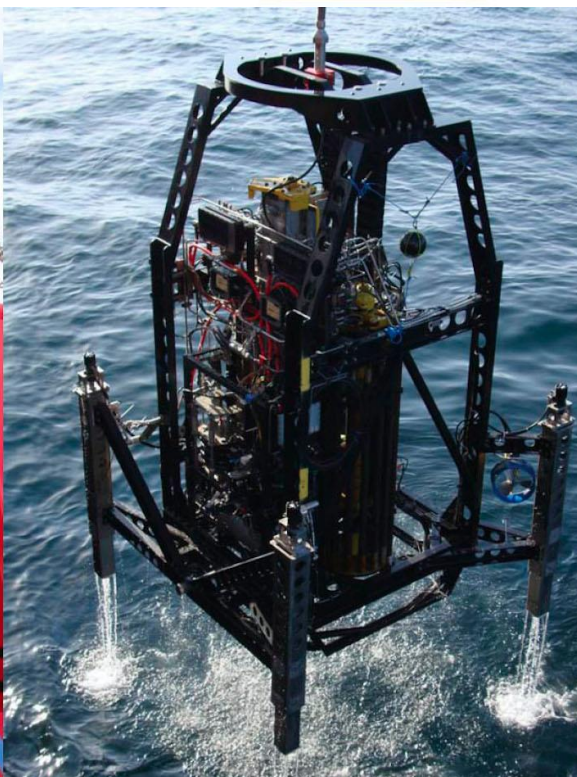
George V Land continental margin



Eocene strata at shallow burial depths: IODP MSP Expedition 373 / Proposal 813 (Williams et al.) planned for 2023 as ECORD Mission Specific Platform



Seabed
Rockdrill:
BGS RD2



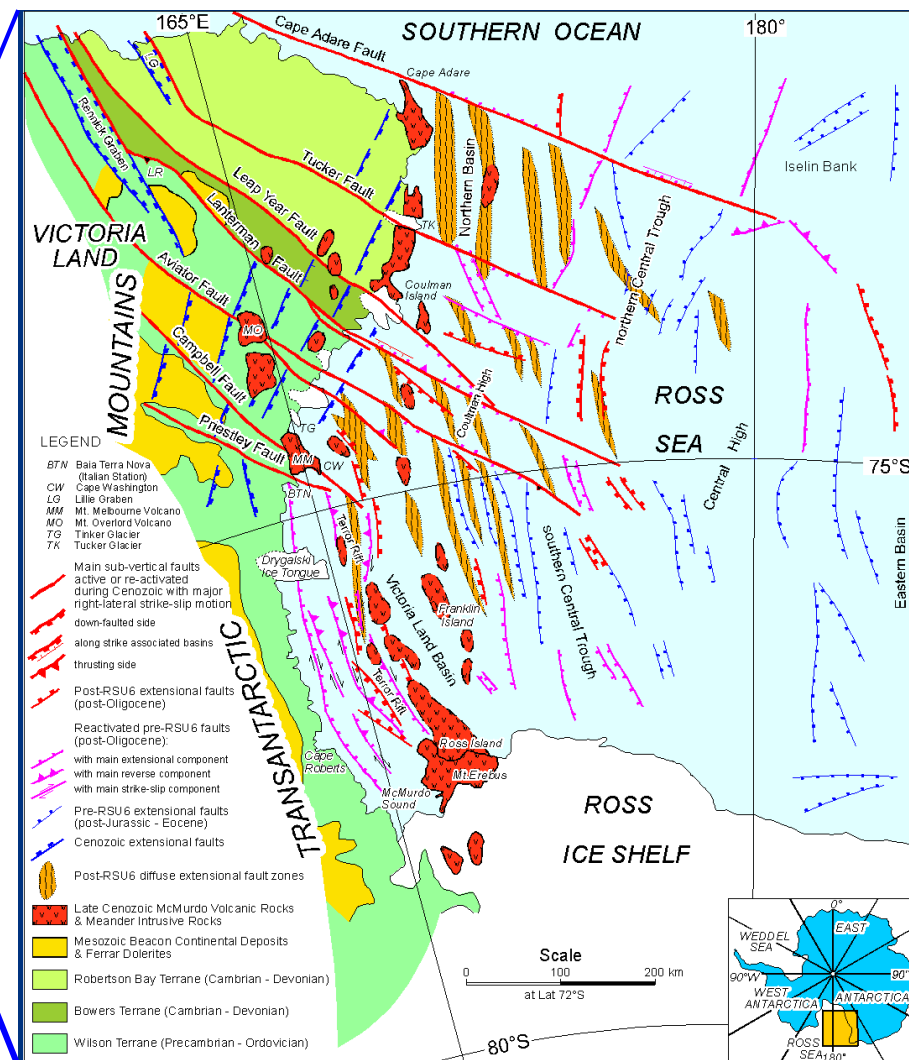
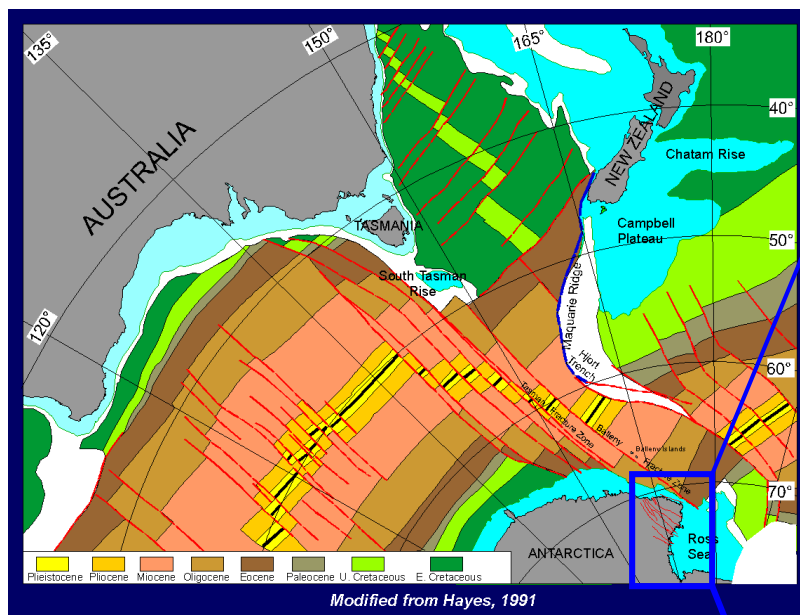
*Vozzhennikova
apertura
Francesca
Sangiorgi*

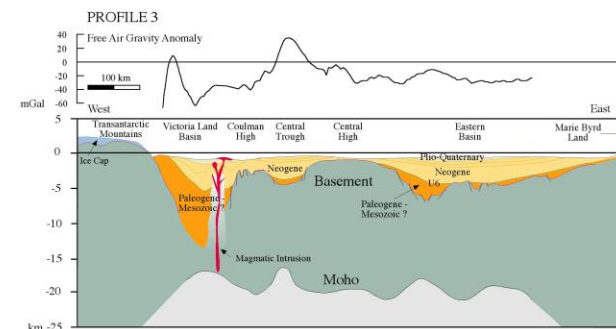
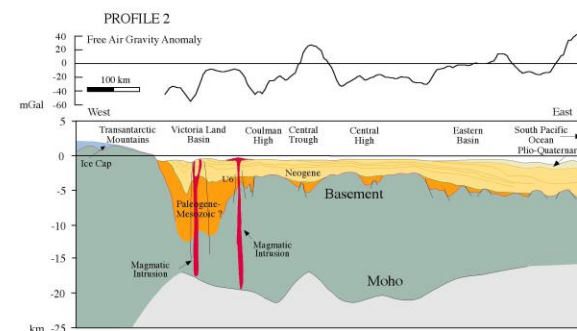
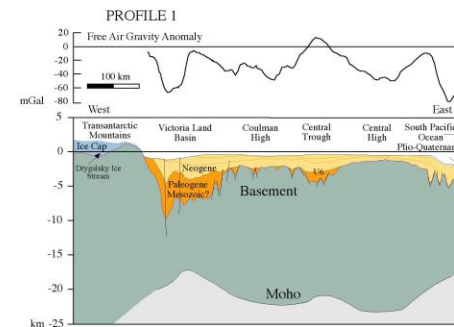
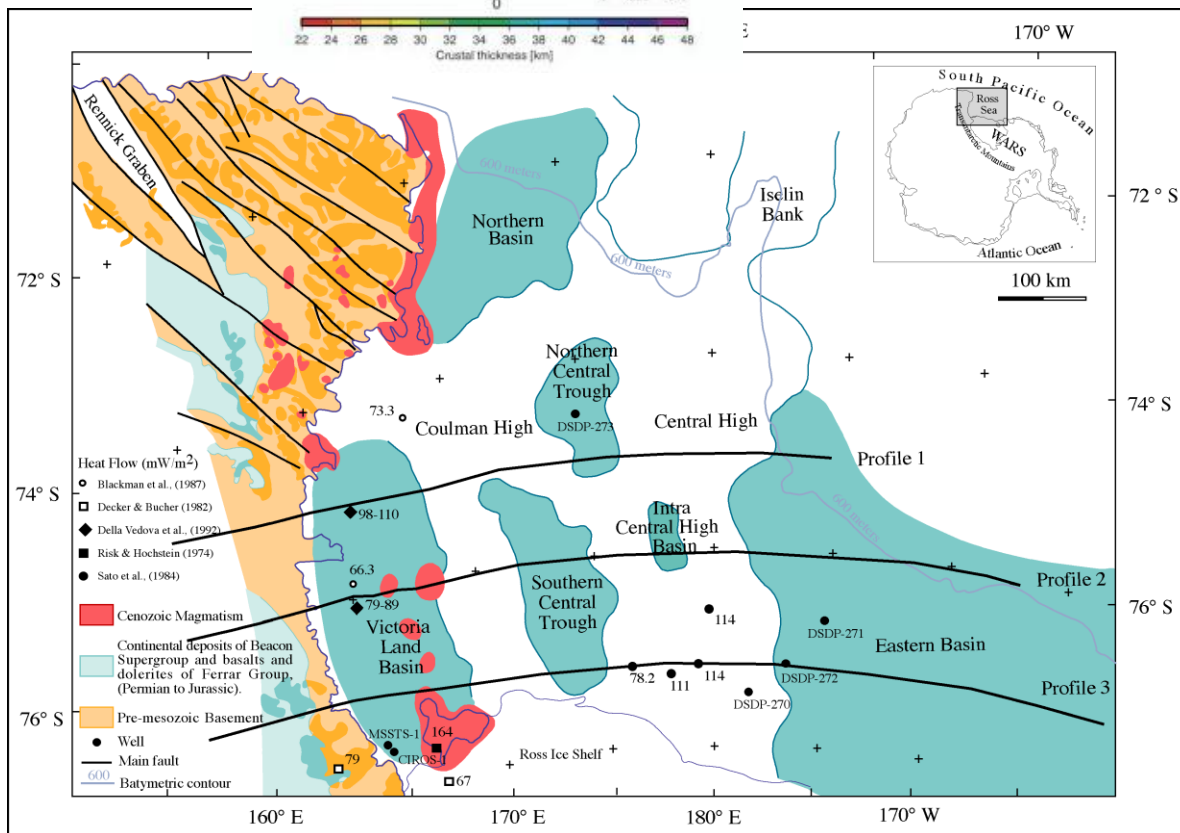
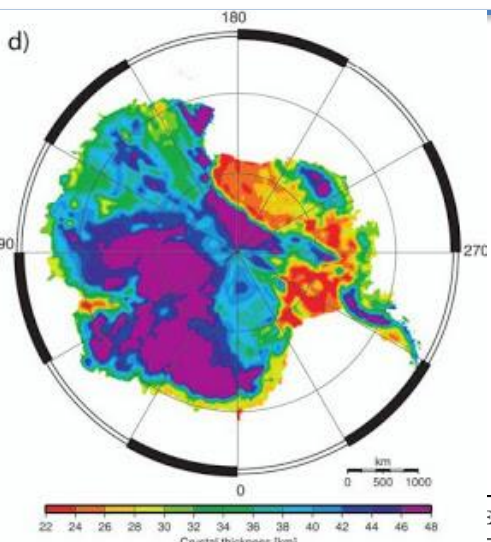


Dredge samples
Leventer, Domack, et al., NBP01-01 2001.
Paleogene lignite present.
New Dredges from Leventer, Domack et al. NBP14-02
Campanian to L. Eocene

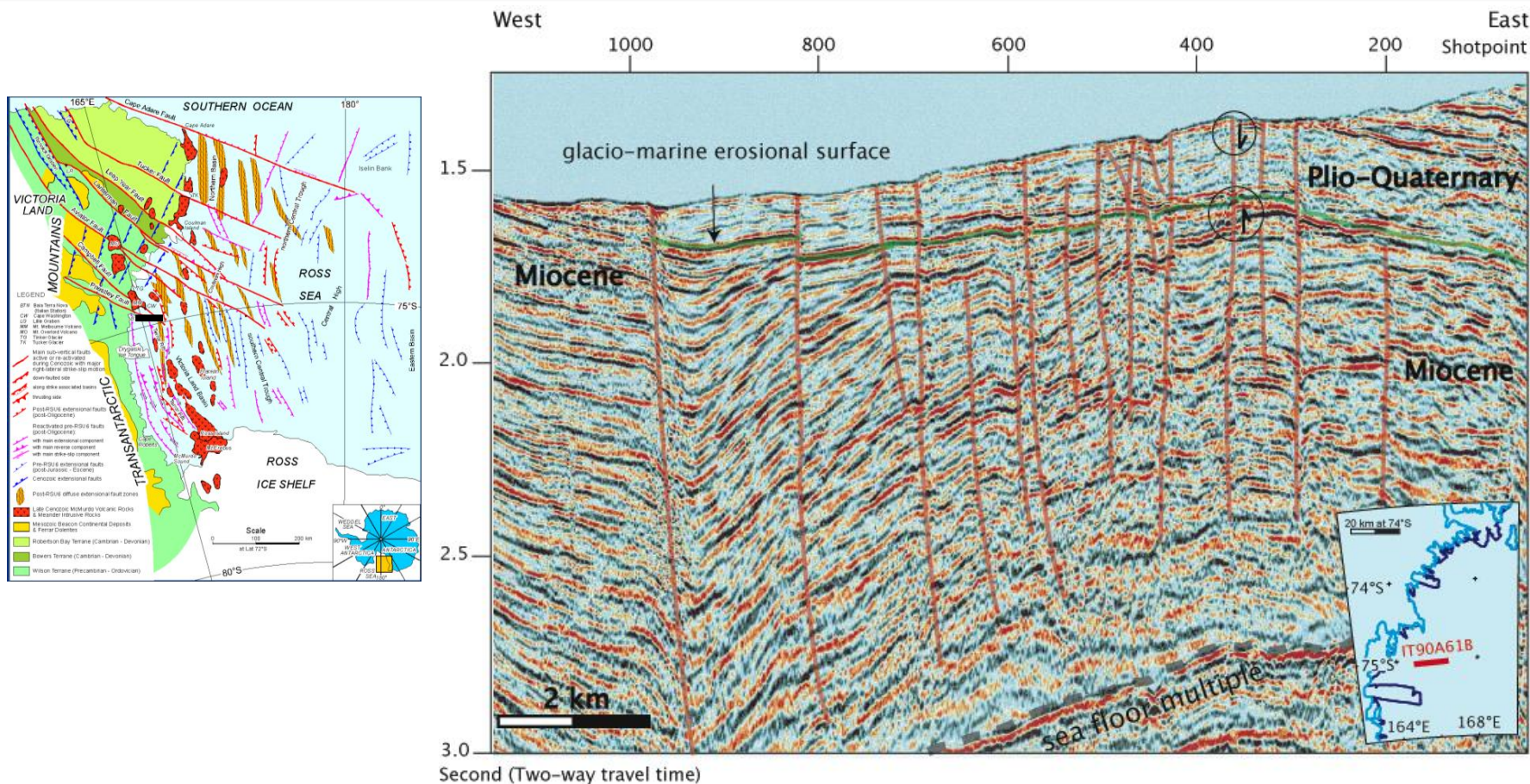
50m
below sea
bed
Max.
4000 m
water-
depth

Il collegamento delle faglie trasformi oceaniche con le faglie trascorrenti della Terra Vittoria e con le strutture nel Mare di Ross



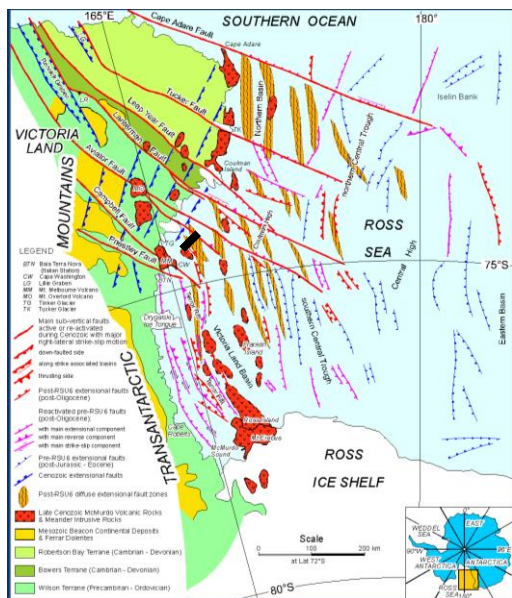
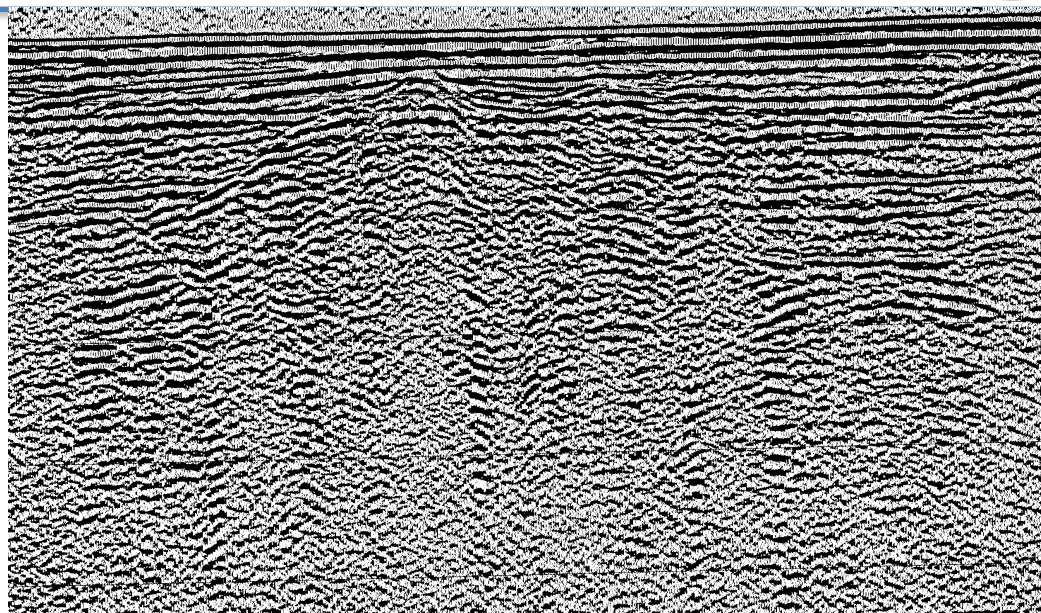


Busetti et al., 1999

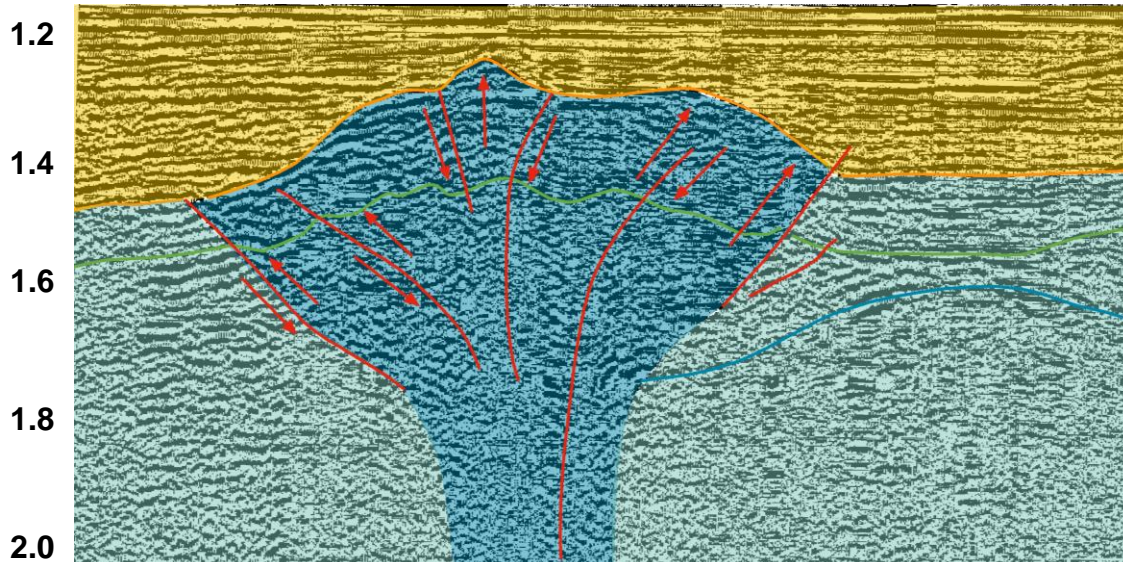


Evidenza della prosecuzione a mare del sistema tettonico legato alla faglia del Ghiacciaio Priestly, trascorrente destra con direzione NW-SE. L'attività è anche neotettonica come dimostra la morfologia del fondo mare caratterizzata da piccoli gradini di faglia.

Faglia transpressiva Struttura a “fiore”



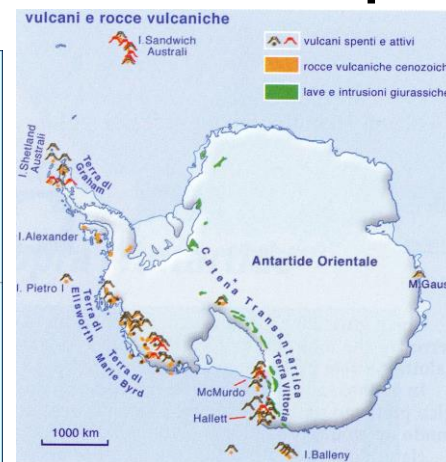
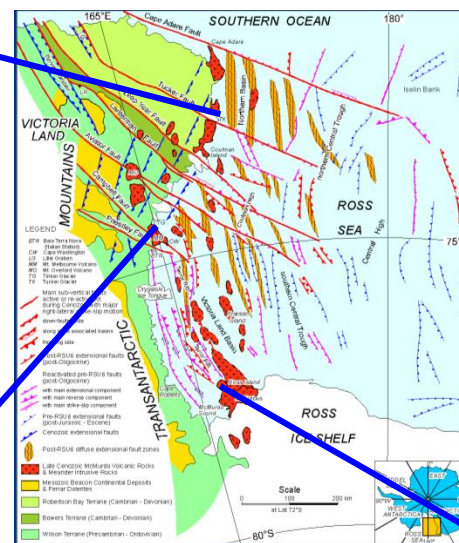
Secondi (Two Way Travel Time)



Salvini et al., 1997 JGR
vol. 102, n. B11

Evidenza della prosecuzione a mare del sistema tettonico legato alla faglia del Ghiacciaio Aviator, trascorrente destra con direzione NW-SE.

Il vulcanismo alcalino Plio-Quaternario del Mc Murdo Volcanic Group



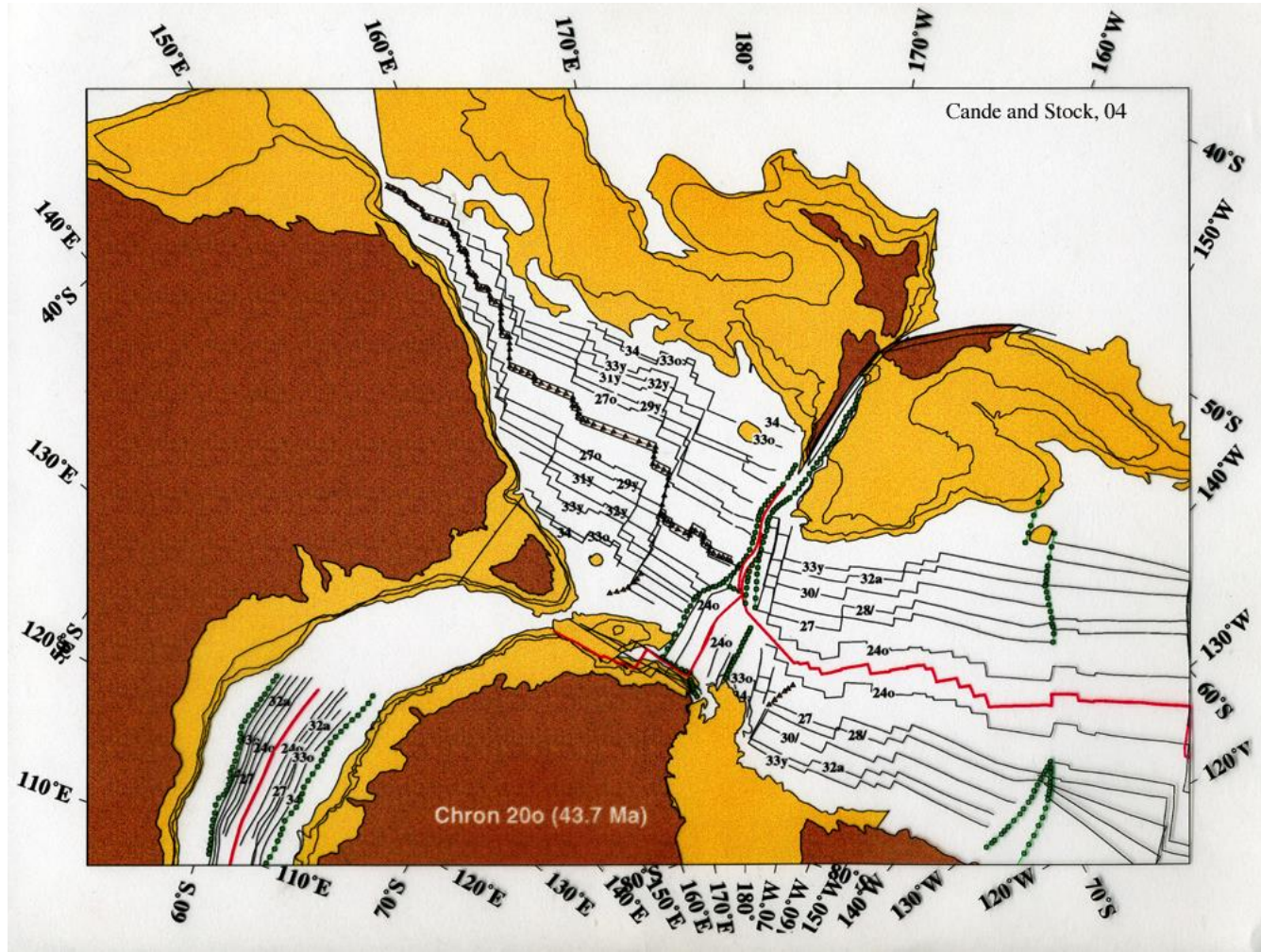
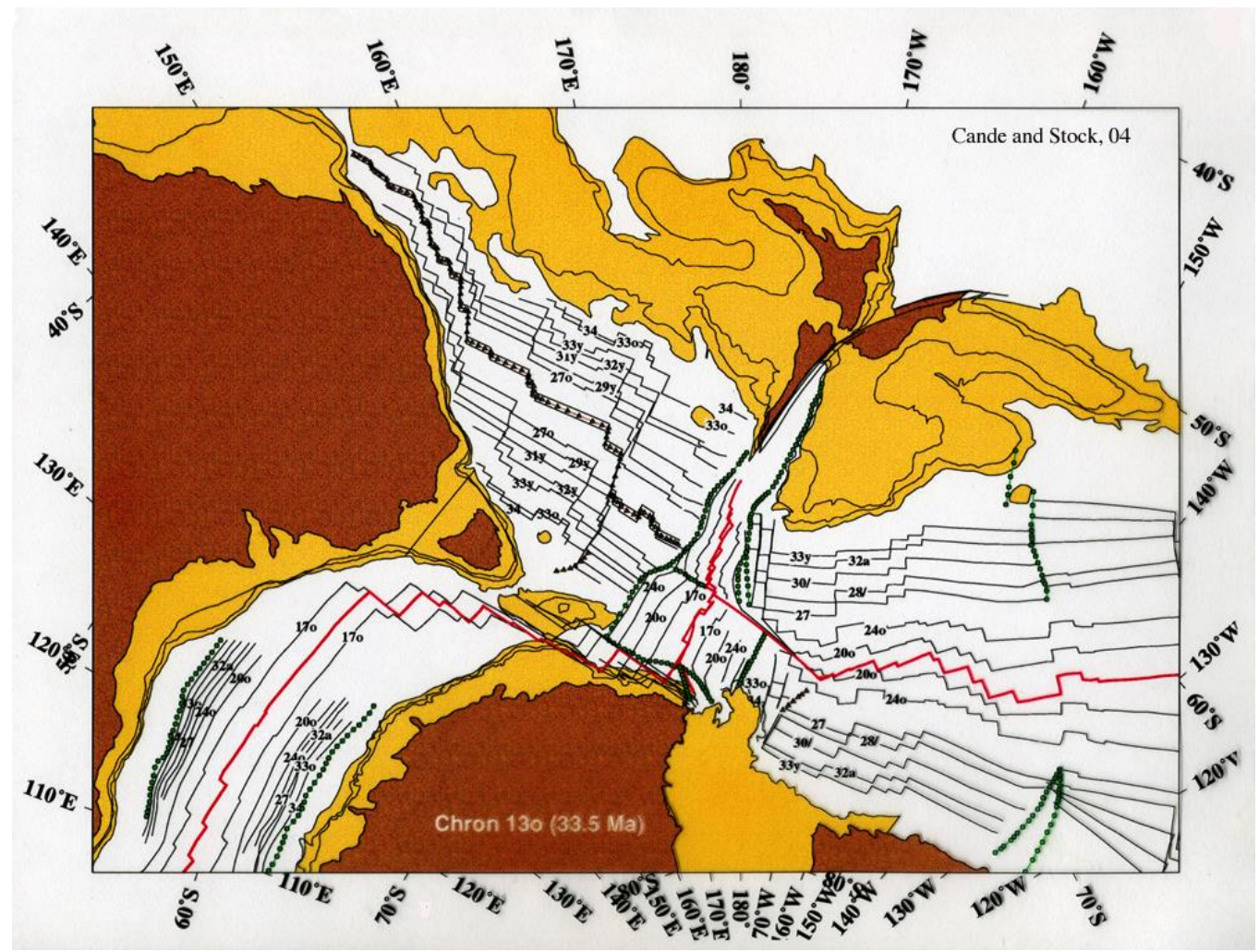
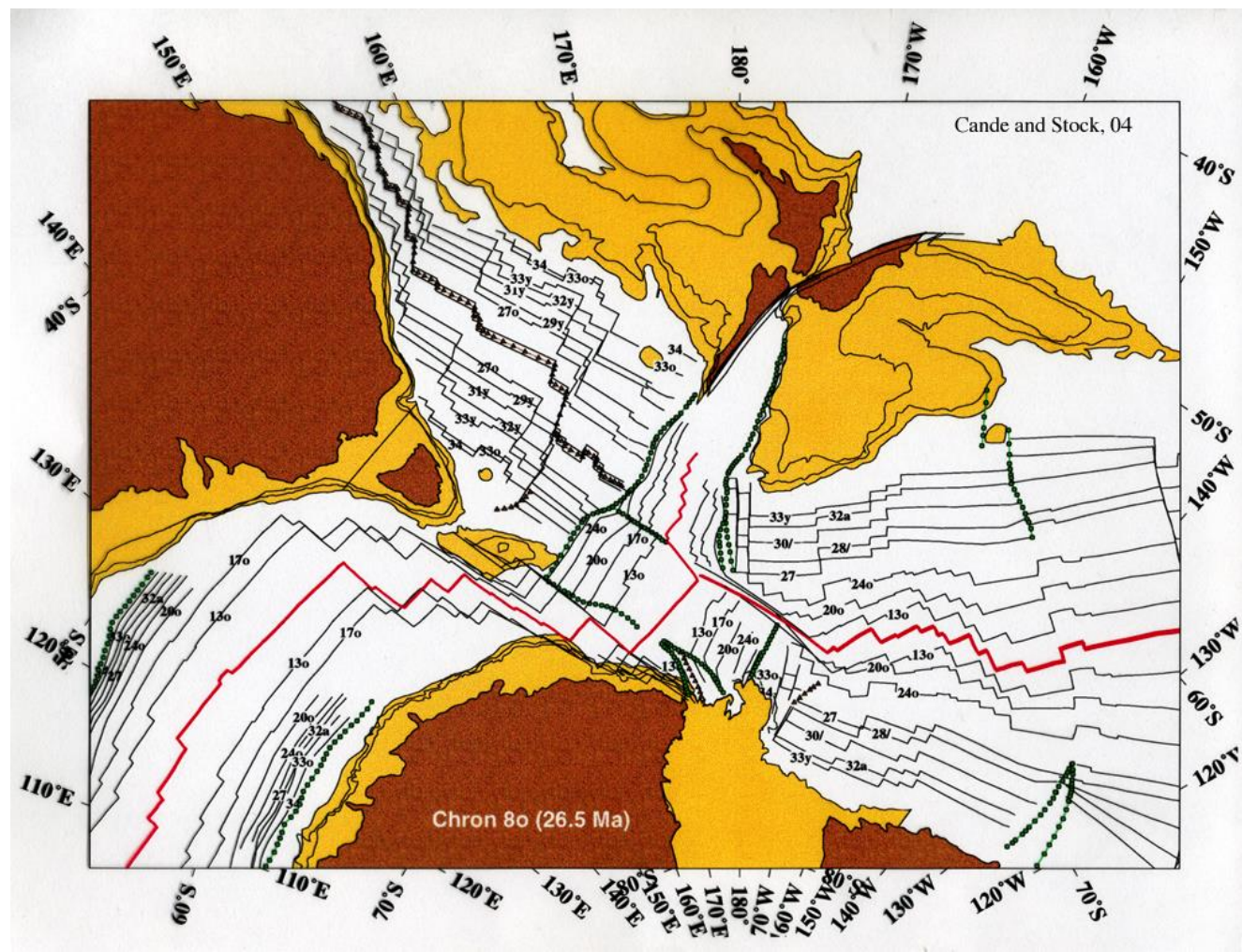


Plate tectonic
Evolution:

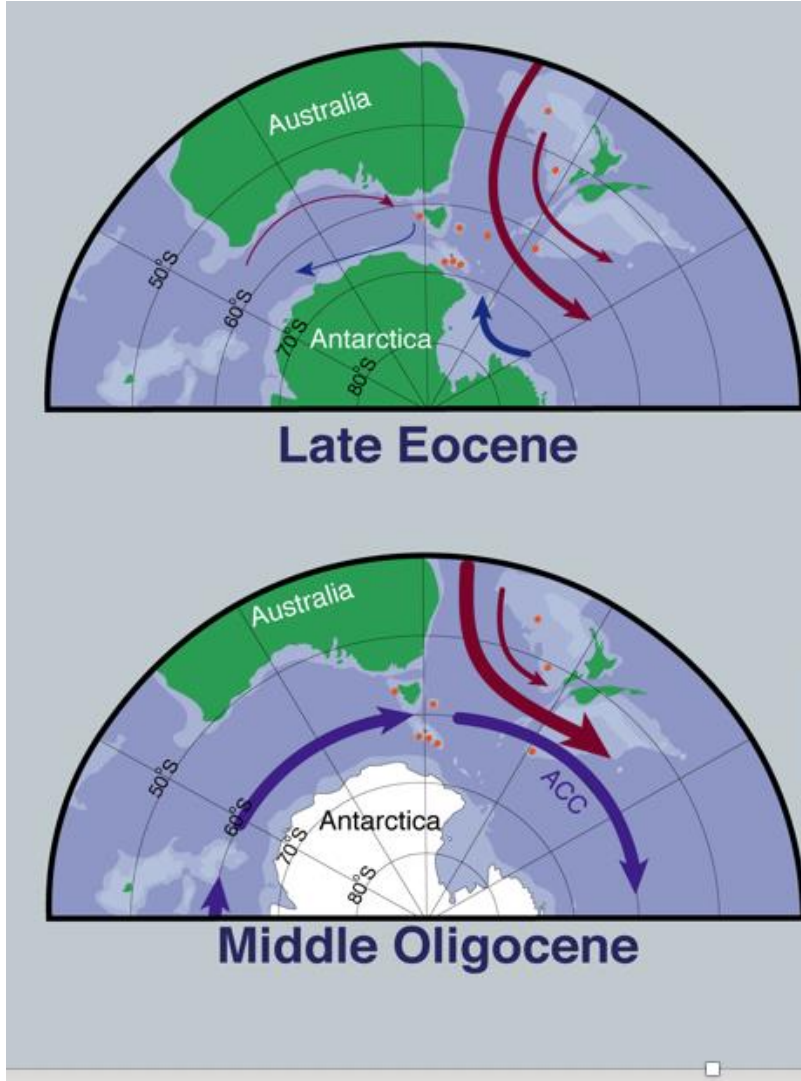
Middle Eocene (44 my)



Eocene / Oligocene Transition (33.5 my)



Late Oligocene (26.5 my)



Ocean Gateway Hypothesis

**Warm Eocene
Ice free continent**

**Opening of the Tasmanian
Gateway during the
Eocene/Oligocene transition**

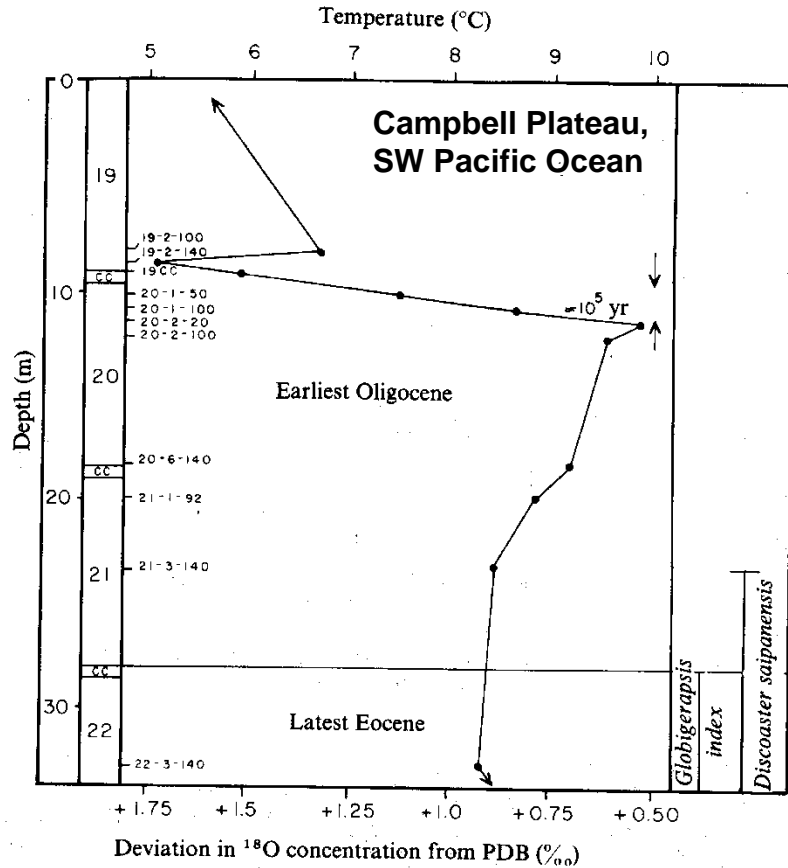
**Initiation of Circum Antarctic
Current**

**Thermal isolation of Antarctica
And Glacial Expansion**

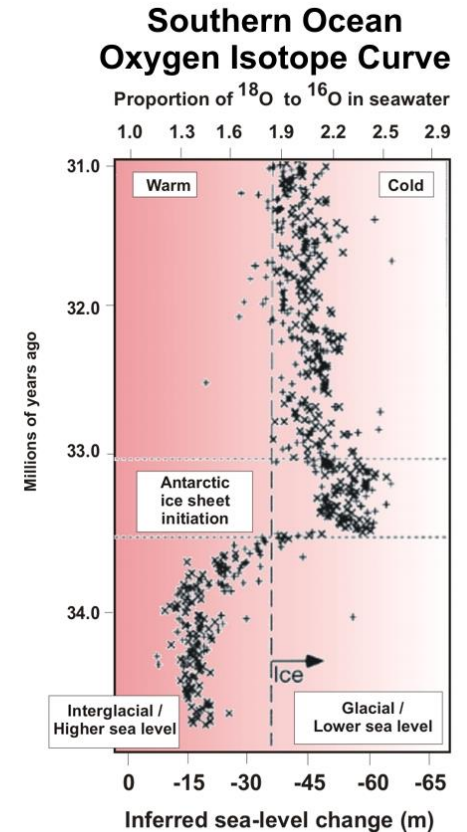
Prior to the first scientific ocean drilling of the Antarctic continental margin in 1973, the prevailing hypothesis was that Antarctica had glaciated at the onset of the Pleistocene (ca. 2.6 Ma). **DSDP Leg 28** provided the first physical evidence for glaciation extending back at least to the late Oligocene (~ 25 Ma; Hayes et al., 1975). Sediments also recorded an increase in ice volume around 14 Ma, interpreted to represent the development of a largely stable East Antarctic Ice Sheet (EAIS; Kennett et al., 1975; Kennett and Shackleton, 1975).

The oxygen isotope ($\delta_{18}\text{O}$) record of foraminifers from sediments collected in the southwest Pacific (about 48°–52°S) during **DSDP Leg 29** indicated that mean annual temperatures at these latitudes were near freezing in the early Oligocene, conditions under which Antarctic glaciers would descend to sea level and sea ice would expand (Shackleton and Kennett, 1975). This led to the hypothesis that the tectonic separation of South America and Australia from Antarctica resulted in the development of the Antarctic Circumpolar Current (ACC), which thermally isolated Antarctica and encouraged ice sheet development (Kennett, 1977).

Geochemical evidence for the onset of Antarctic glaciations at c. 34 Ma



Kennett and Shackleton (1976), *Nature*, DSDP Site 277



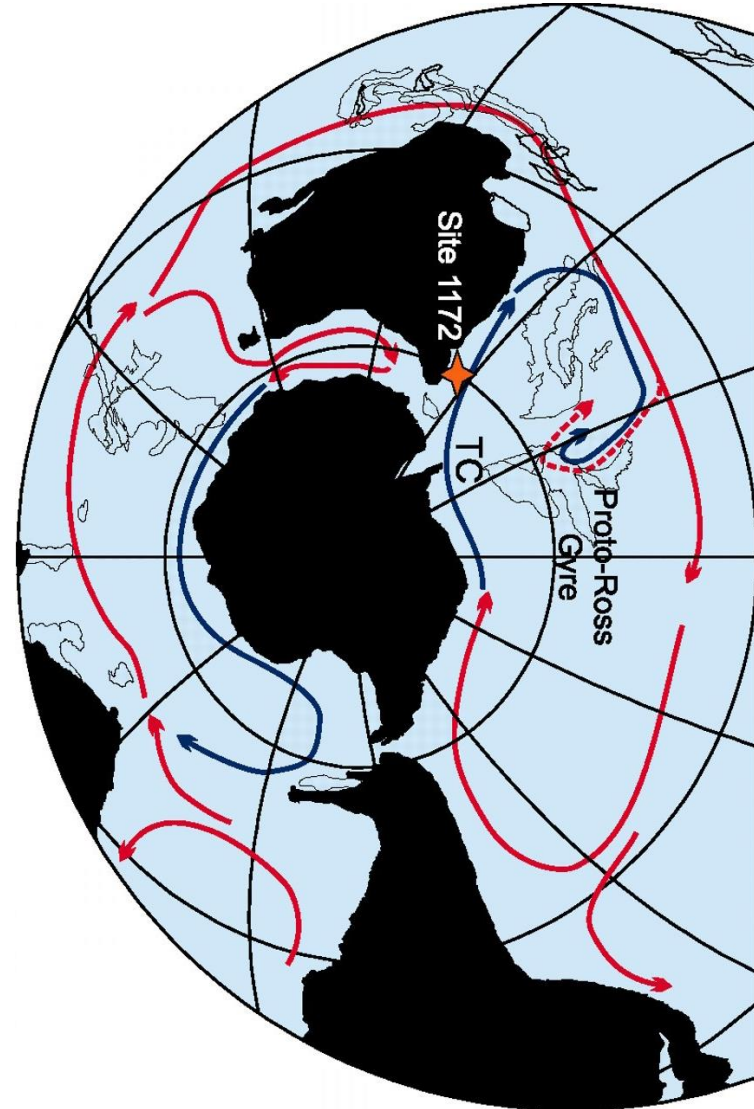
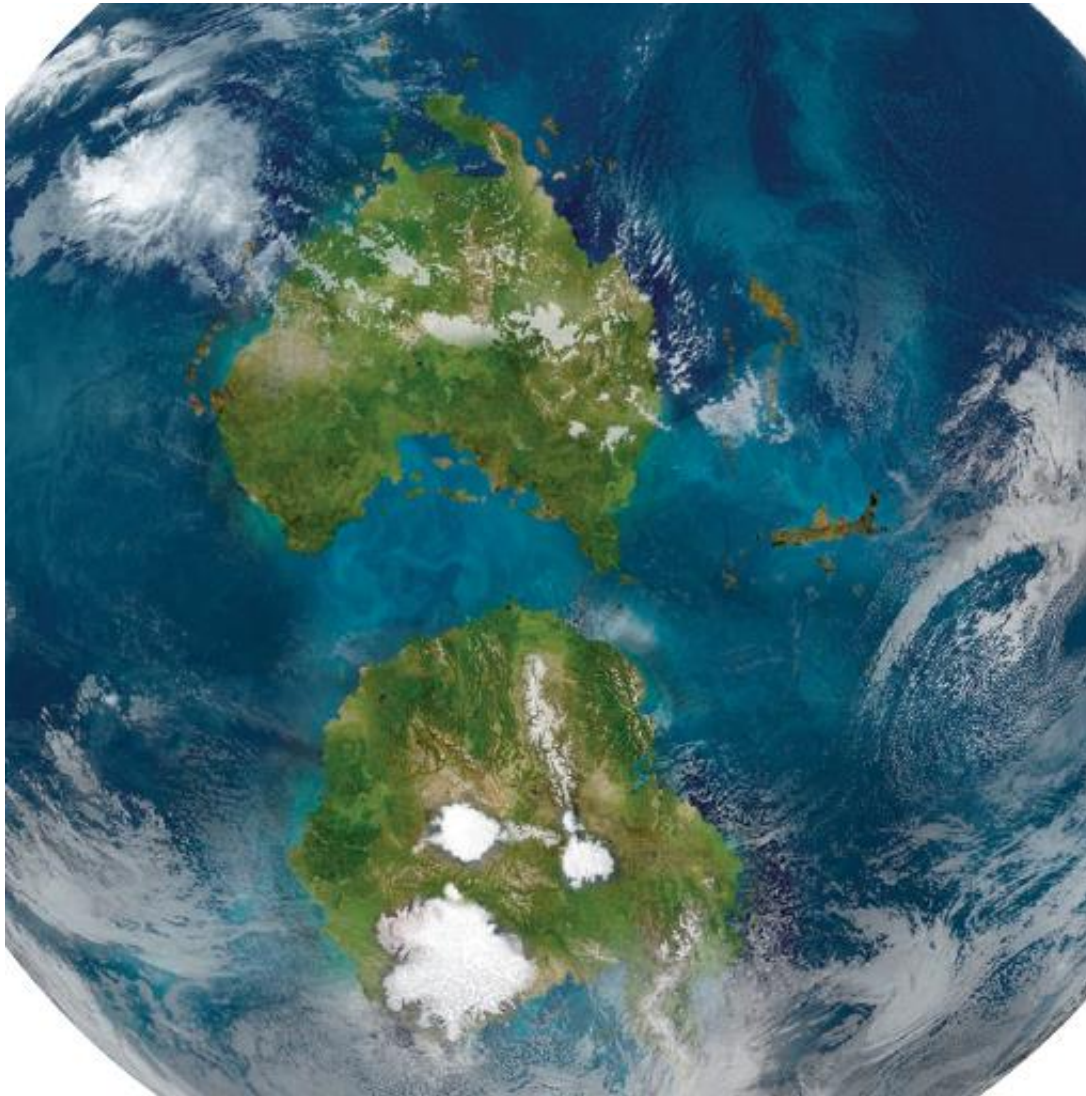
Zachos et al. (1996), *Paleoceanography*, ODP Site 677

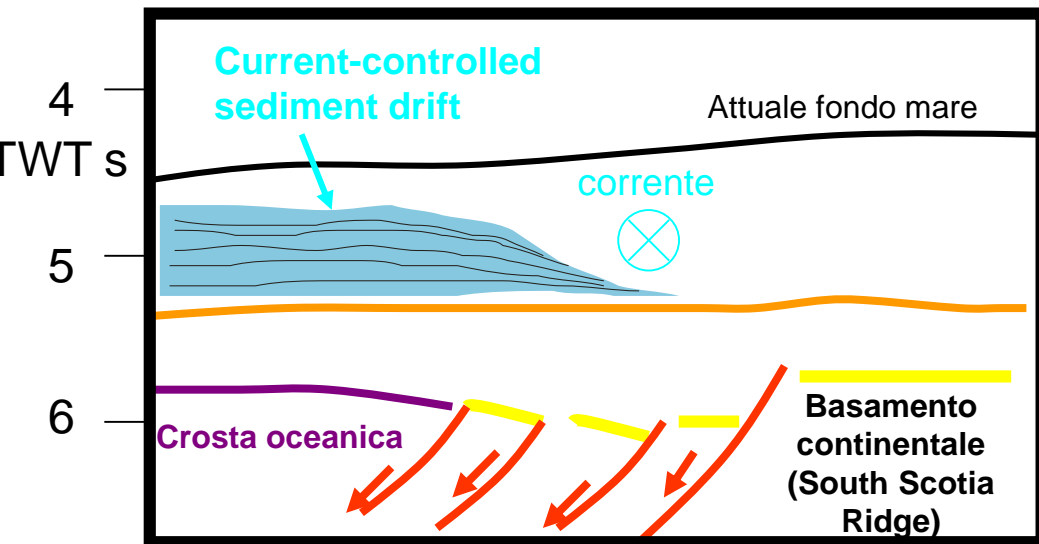
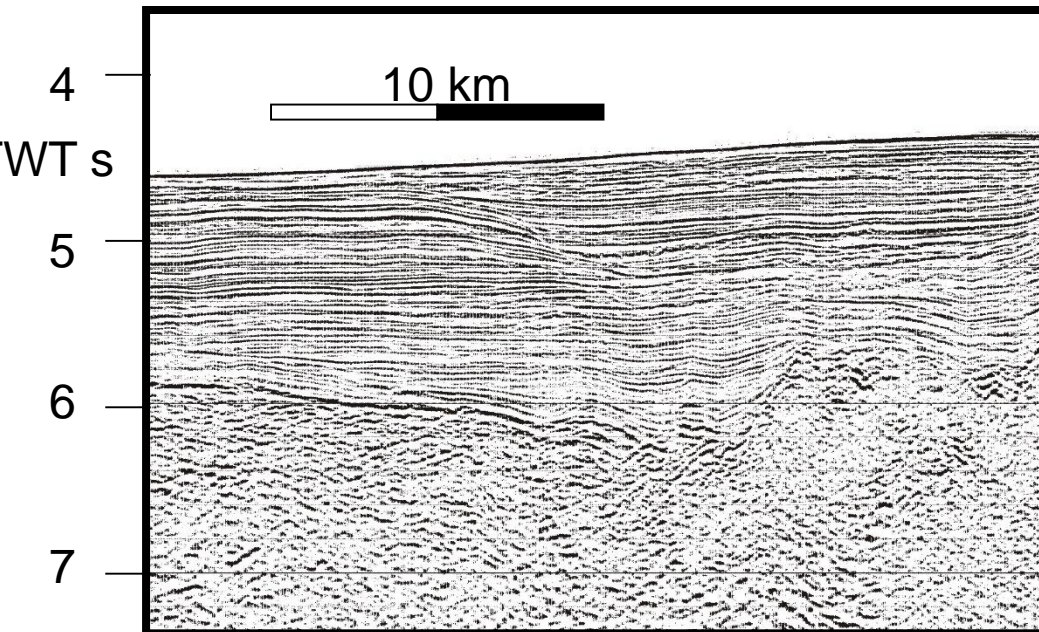
The Eocene warmth was followed by cooling, declining atmospheric CO₂ and concurrent tectonic reorganizations that culminated in continental-scale glaciation of Antarctica at around 34 Ma (the Eocene-Oligocene transition; EOT).

DSDP Leg 28 drilling in the eastern Ross Sea continental shelf was first to recover diamict sediments (ice-proximal glacial deposits), evidence that grounded ice from the WAIS first developed around 25 Ma (Hayes et al., 1975).

Subsequent drilling from sea ice platforms (CIROS and CRP projects) revealed slightly older AIS glacial expansion in the earliest Oligocene (Barrett, 1989, 2007) that was restricted to the continent and was highly responsive to orbital forcing (Galeotti et al., 2016).

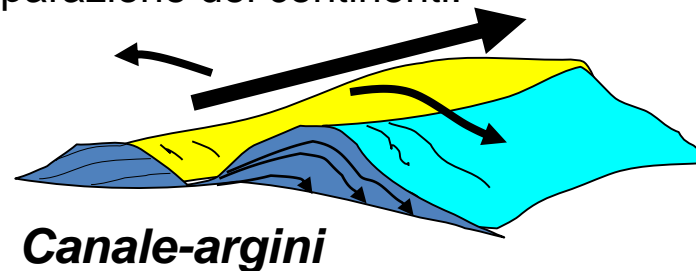
Thermal isolation of Antarctic ~35 Ma when ocean gateways opened – *James Kennett's hypothesis*





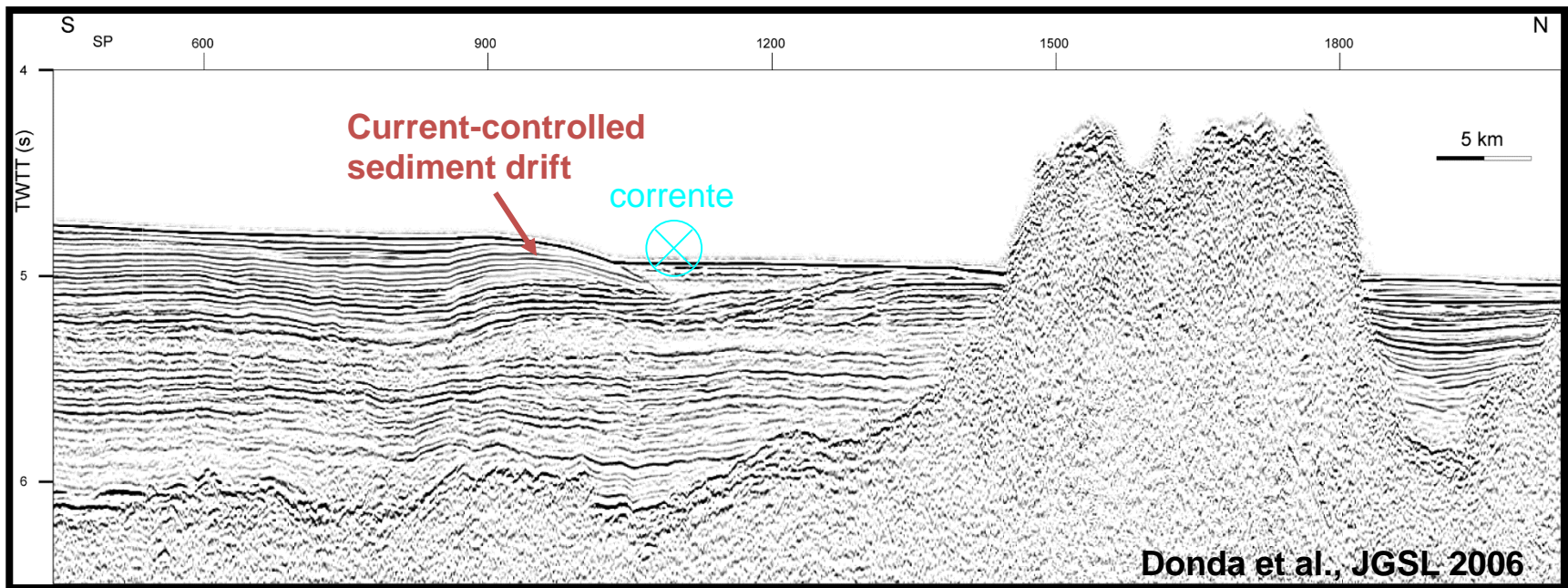
La presenza di **Sediment drift** (strutture tipicamente originate da correnti che scorrono sul fondo oceanico) sepolti, all'interno della successione sedimentaria *post-rift*, rappresentano l'evidenza dell'inizio del passaggio della corrente di fondo circum-antartica attraverso lo stretto di Drake.

Sediment drift più recenti ed attuali si trovano via via più a sud e testimoniano la migrazione delle correnti in relazione alla separazione dei continenti.

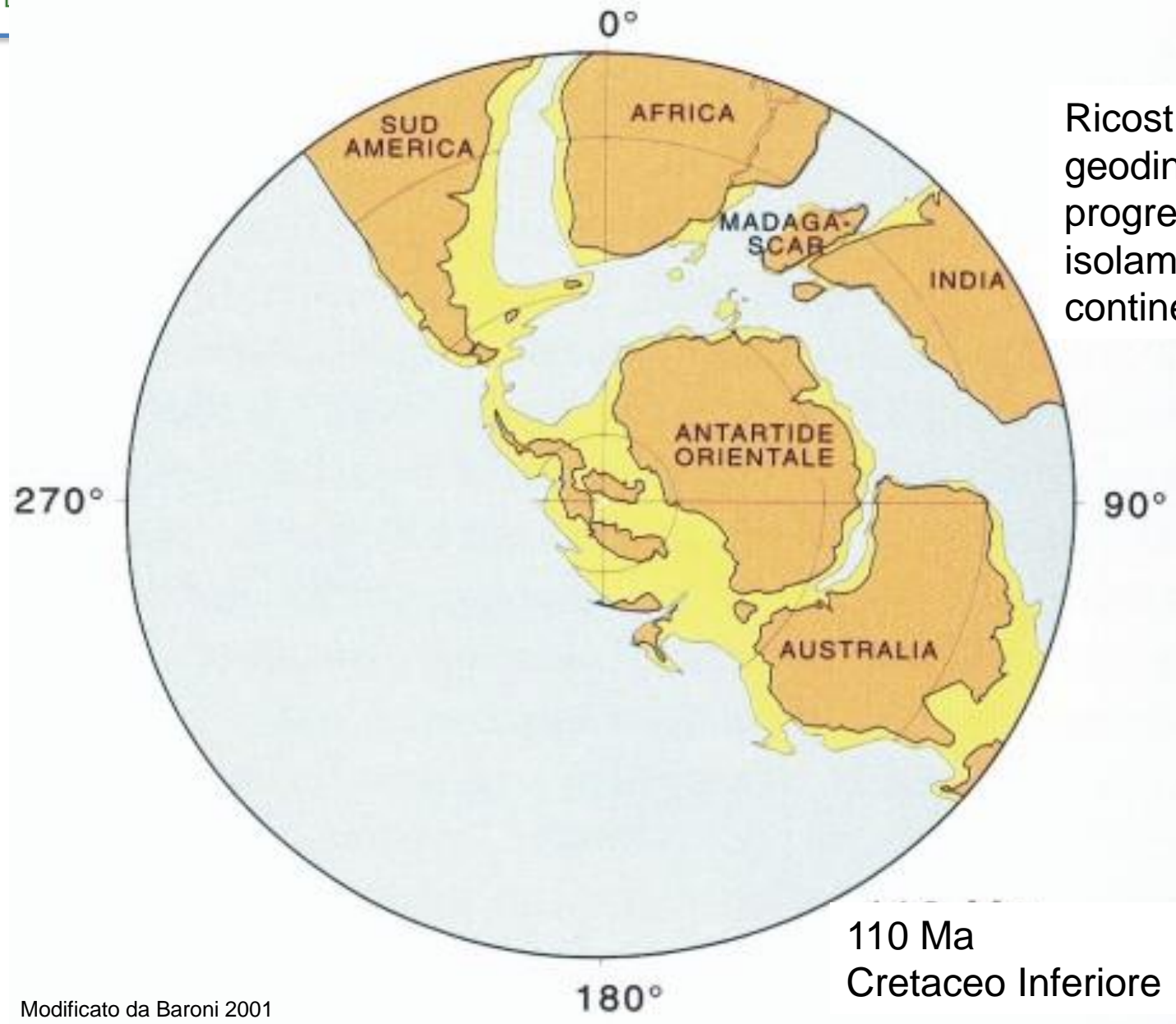


SEDIMENT DRIFT: corpo sedimentario formato da correnti di fondo

Linea sismica multicanale Australiana (Oceano Indiano)



*La presenza di Sediment drift, all'interno della successione sedimentaria post-rift, rappresenta l'evidenza del passaggio della corrente di fondo circum-antartica attraverso il *Tasman Gate*.*

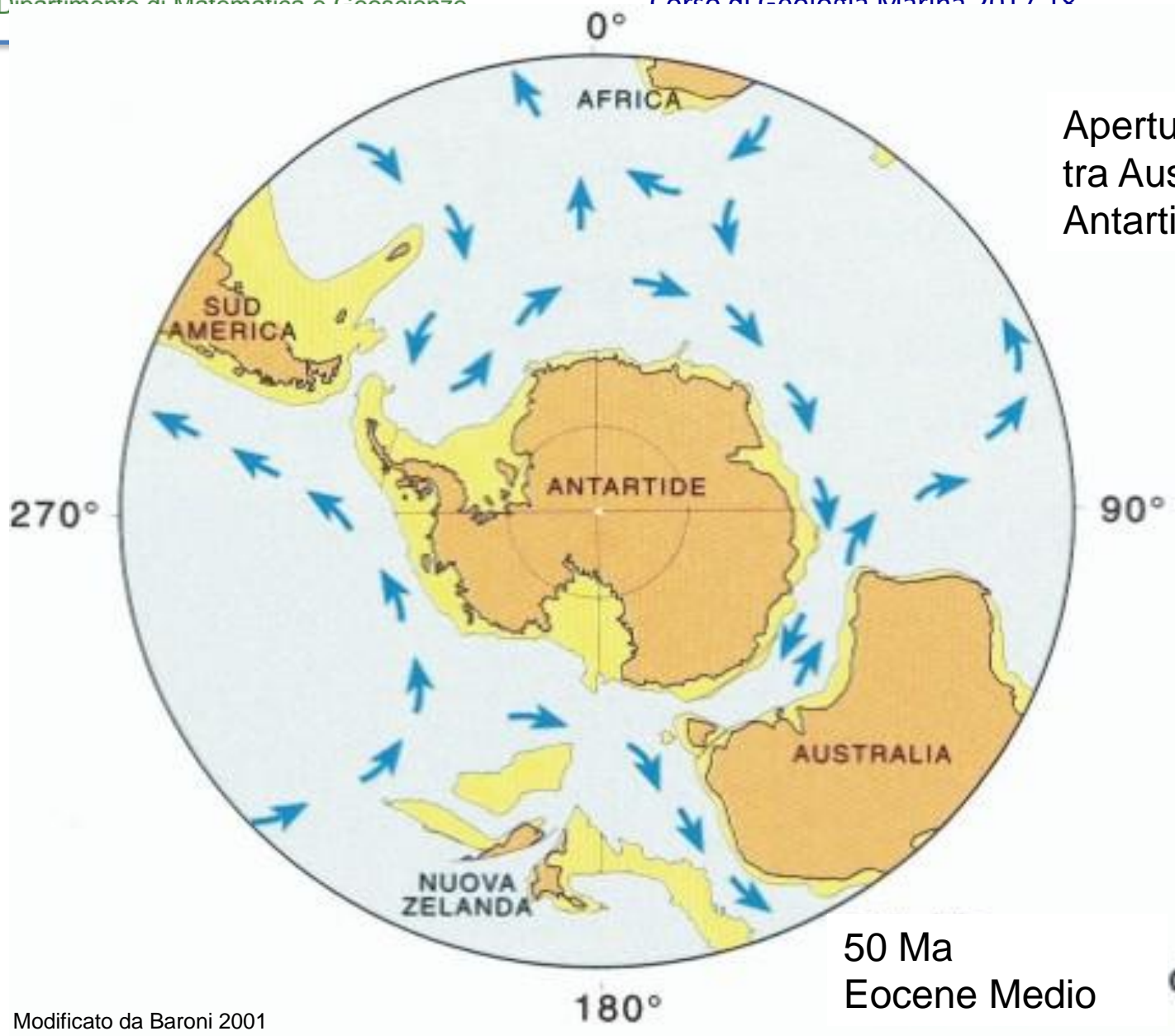


Ricostruzioni
geodinamiche del
progressivo
isolamento del
continente antartico

Modificato da Baroni 2001

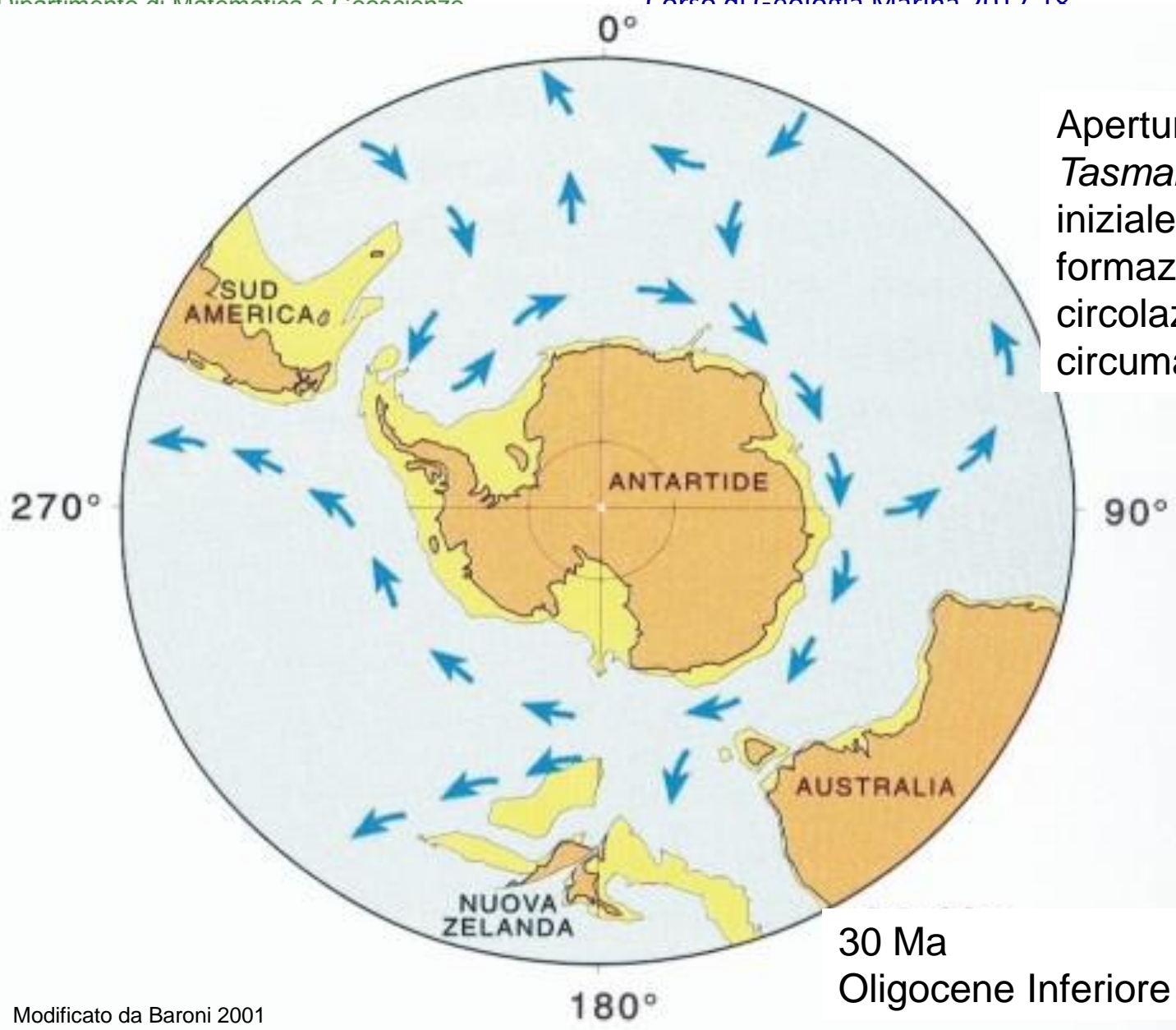
110 Ma
Cretaceo Inferiore

Apertura di un golfo
tra Australia ed
Antartide orientale



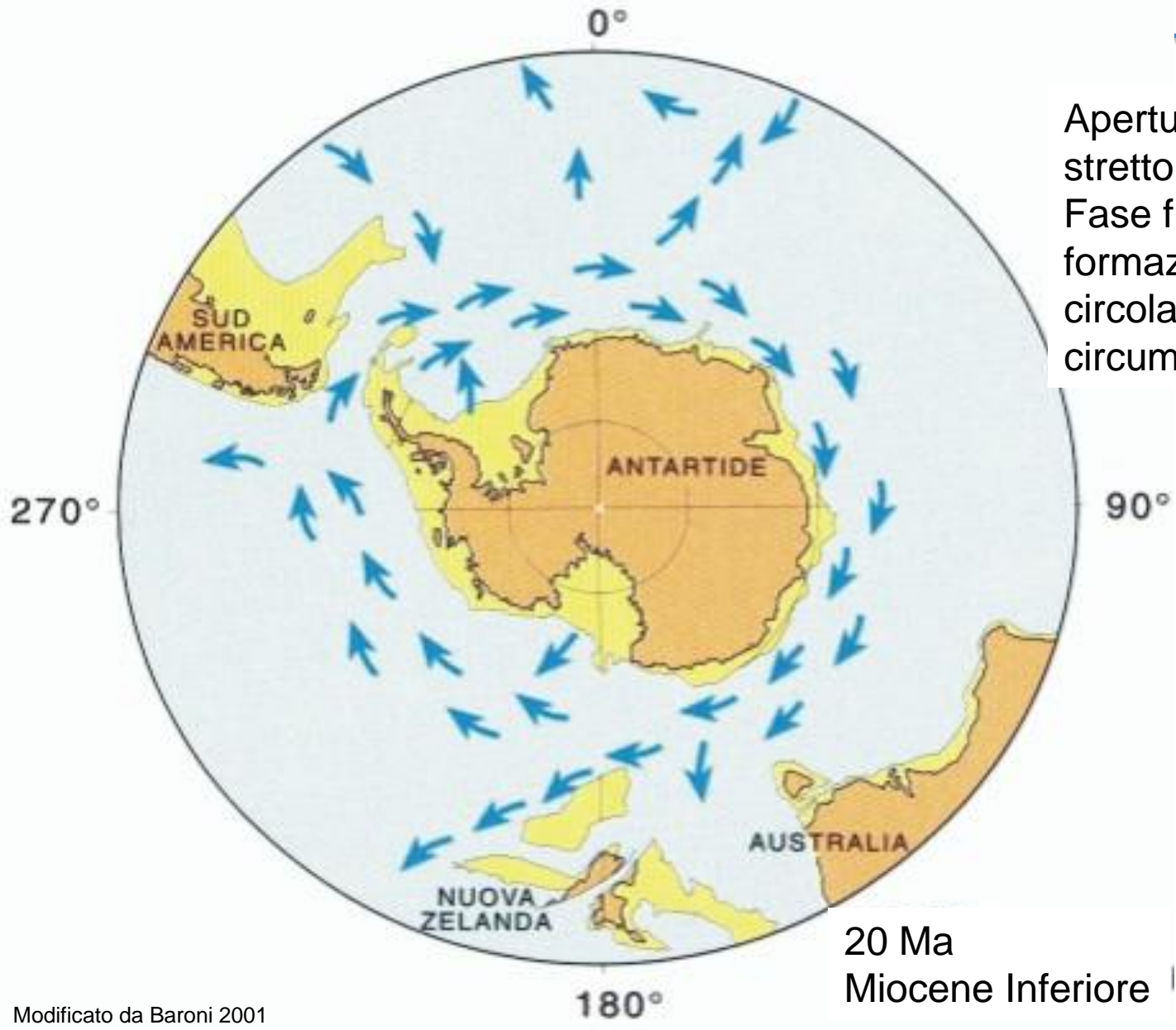
Modificato da Baroni 2001

50 Ma
Eocene Medio



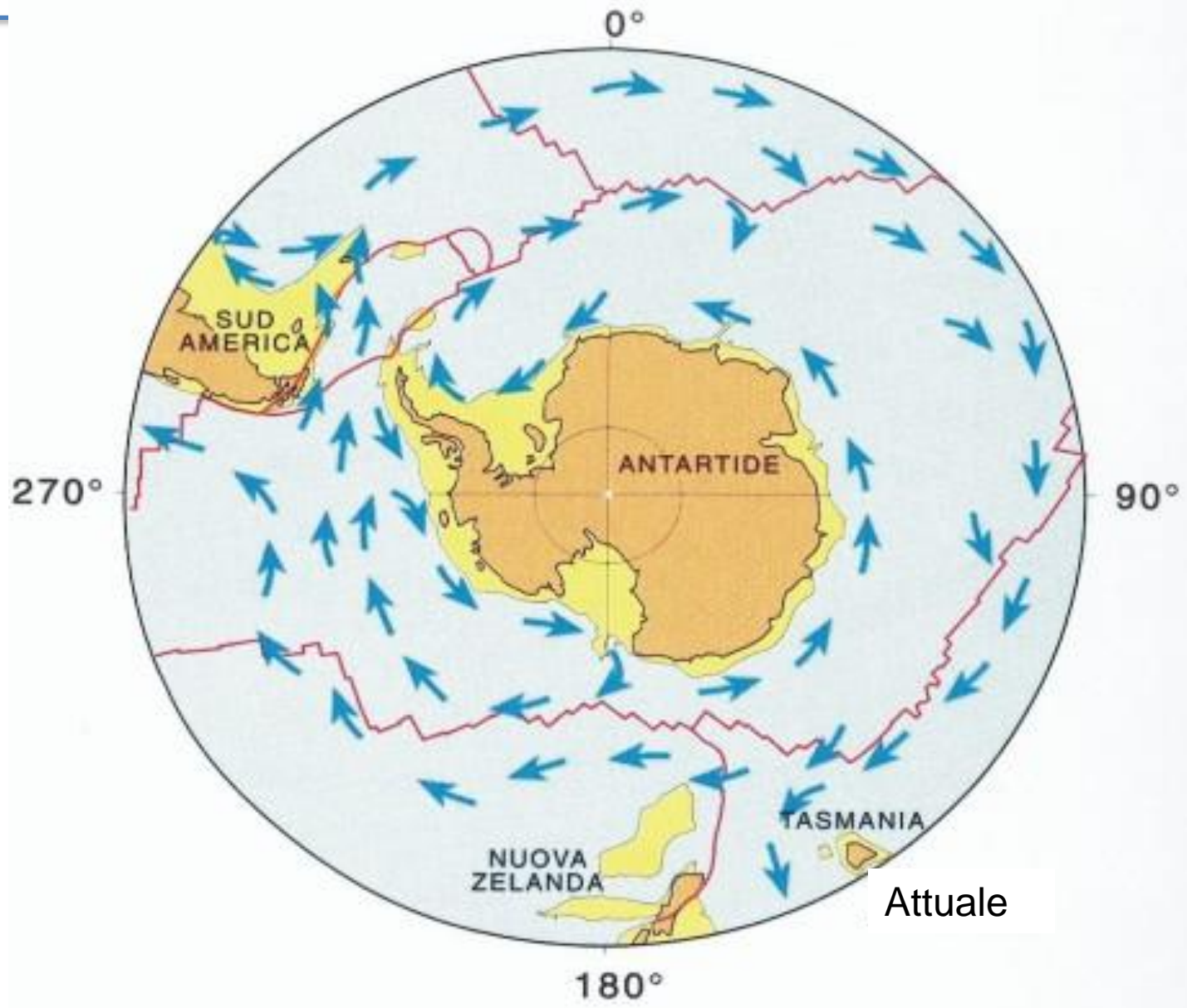
Apertura del
Tasman Gate: fase
iniziale della
formazione della
circolazione
circumantartica

30 Ma
Oligocene Inferiore



Apertura dello stretto di Drake:
Fase finale della
formazione della
circolazione
circumantartica

20 Ma
Miocene Inferiore

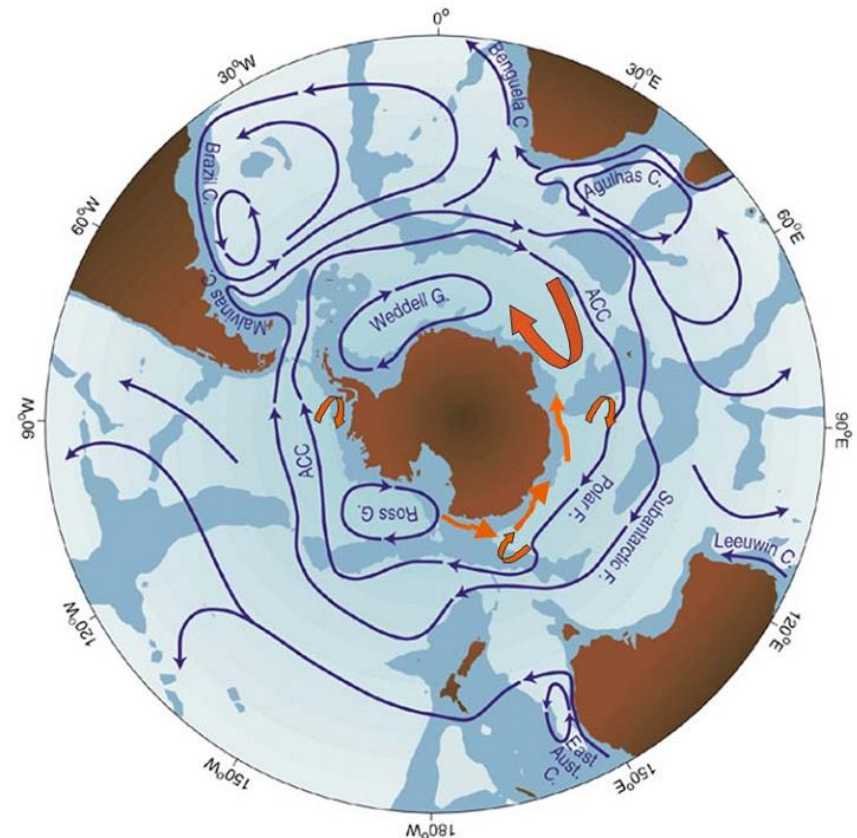
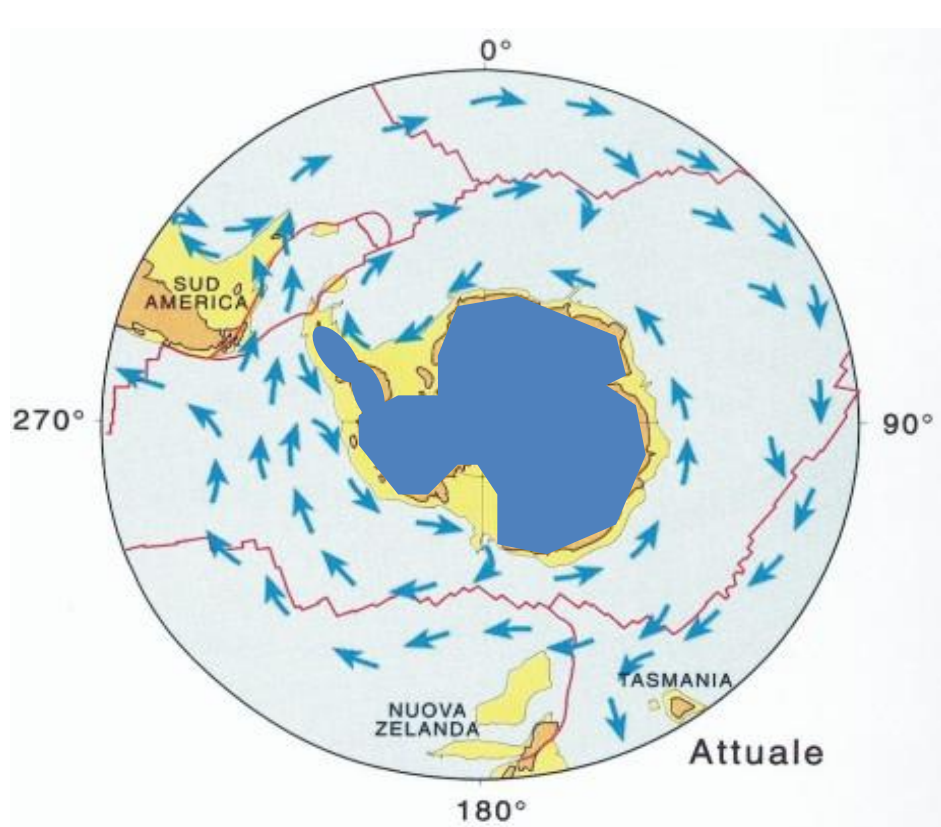


La storia post-Giurassica di Gondwana è caratterizzata dalla frammentazione dei vari blocchi continentali e dal loro successivo allontanamento verso le attuali posizioni. Il primo episodio (a) si è verificato (c. 130 Ma) ed ha interessato il Gondwana occidentale con lo sviluppo dell'oceano proto-Indiano e la separazione di Africa e sud America. A 125 Ma comincia ad aprirsi l'Atlantico meridionale che porterà intorno a 80 Ma di anni fa alla separazione fra Africa e sud America. A 110 Ma (b), l'apertura di un ramo laterale dell'Indiano conduce alla separazione dell'India che comincia la sua migrazione verso nord, fino alla collisione con l'Asia e conseguente creazione della catena Hymalaiana. Intorno a 60 Ma si fa risalire la separazione Antartide – Australia, ma è circa 30 Ma fa (c), che in seguito al distacco della Penisola Antartica dal sud America, con la formazione dello stretto di Drake e lo sviluppo della corrente circumpolare antartica, che l'Antartide raggiunse il completo isolamento intorno al polo sud (d) che determinerà lo sviluppo della potente calotta glaciale.

ACC transport of 100-150 Sverdrups ($1 \text{ Sv} = 10^6 \text{ m}^3 \text{ s}^{-1}$).

Mean ACC temperature ranges from -1 to 5°C , depending on the time of year and location. The mean surface salinity decreases poleward, in general, from 34.9 at 35°S to 34.7 at 65°S .

The ACC extends from the sea surface to depths of 2000-4000 m and can be as wide as 2000 km. ACC flows eastward at 20 cm s^{-1} in regions between the fronts, driven by strong westerly winds. The average wind speed between 40°S and 60°S is 15 to 24 knots with strongest winds typically between 45°S and 55°S .



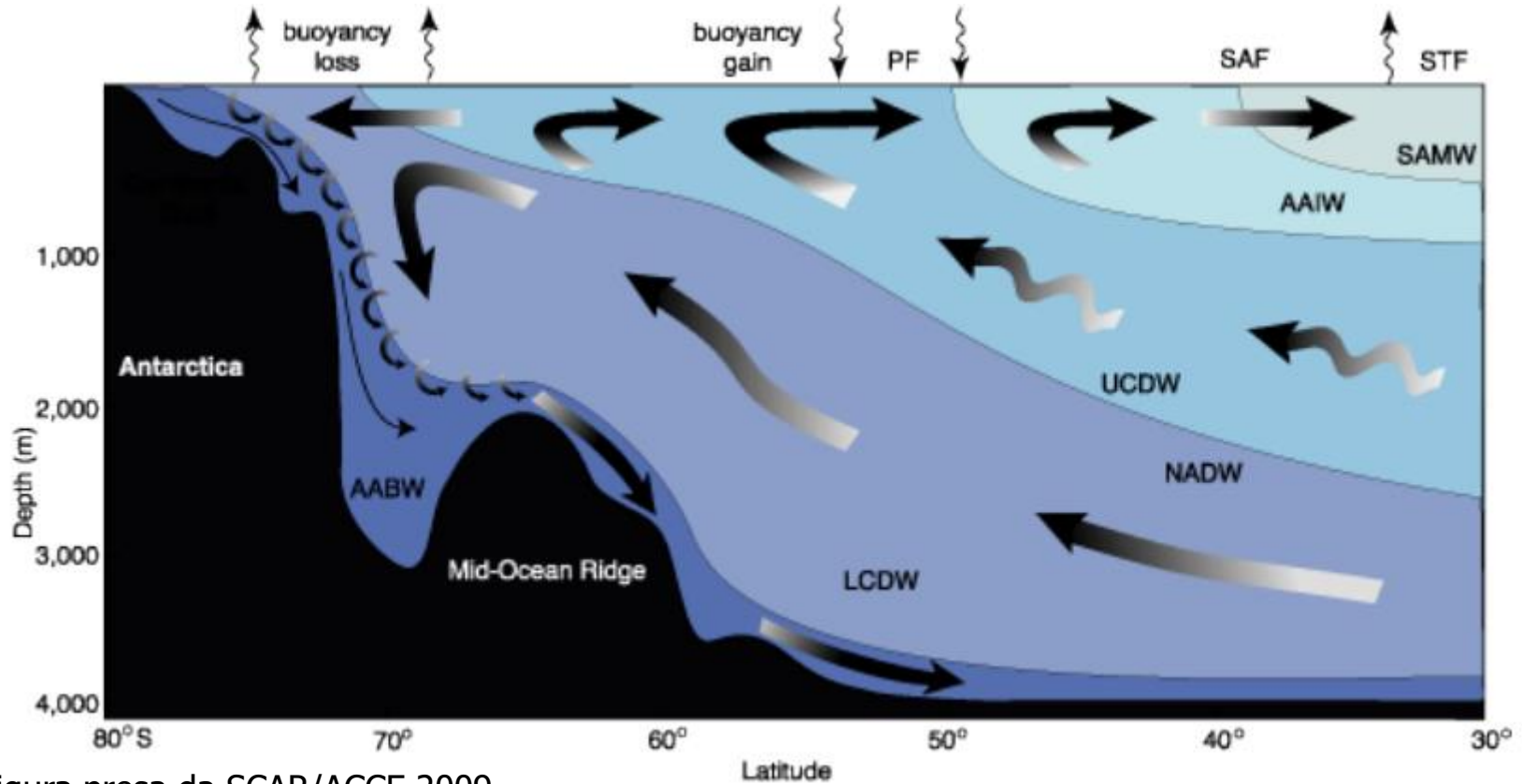


Figura presa da SCAR/ACCE 2009

PF – Polar Front; SAF – Sub-Antarctic Front; and STF – Subtropical Front
AABW – Antarctic Bottom Water; LCDW and UCDW, Lower and Upper Circumpolar Deep Waters; NADW – North Atlantic Deep Water; AAIW – Antarctic Intermediate Water and SAMW – Sub-Antarctic Mode Water (from Speer et al., 2000).

