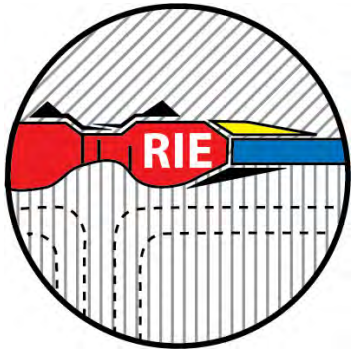
Geo PRISMS

Geodynamic Processes at Rifting and Subducting Margins



The life cycle of rifted margins

Harm Van Avendonk
University of Texas Institute for Geophysics
Austin TX

GeoPRISMS DLP seminar in the Pink Palace
Memphis, TN
November 12, 2011

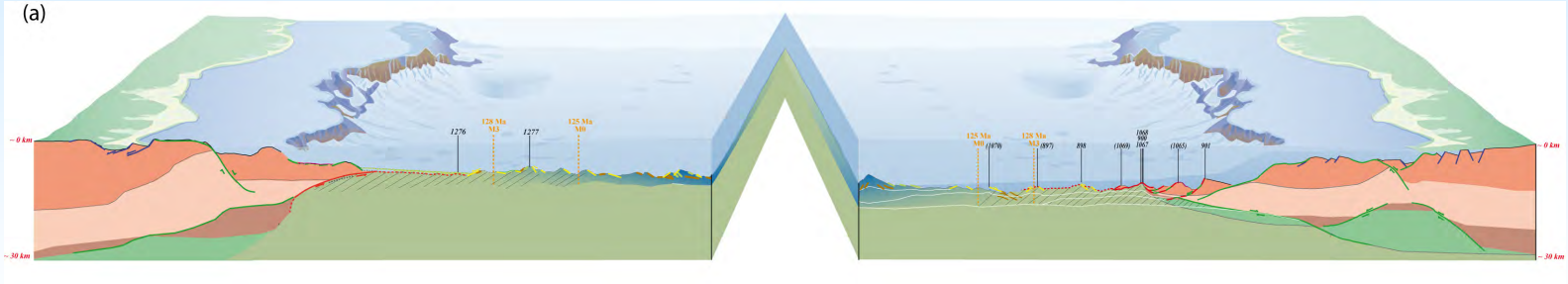


Plate tectonics

Breakup of continents and seafloor spreading

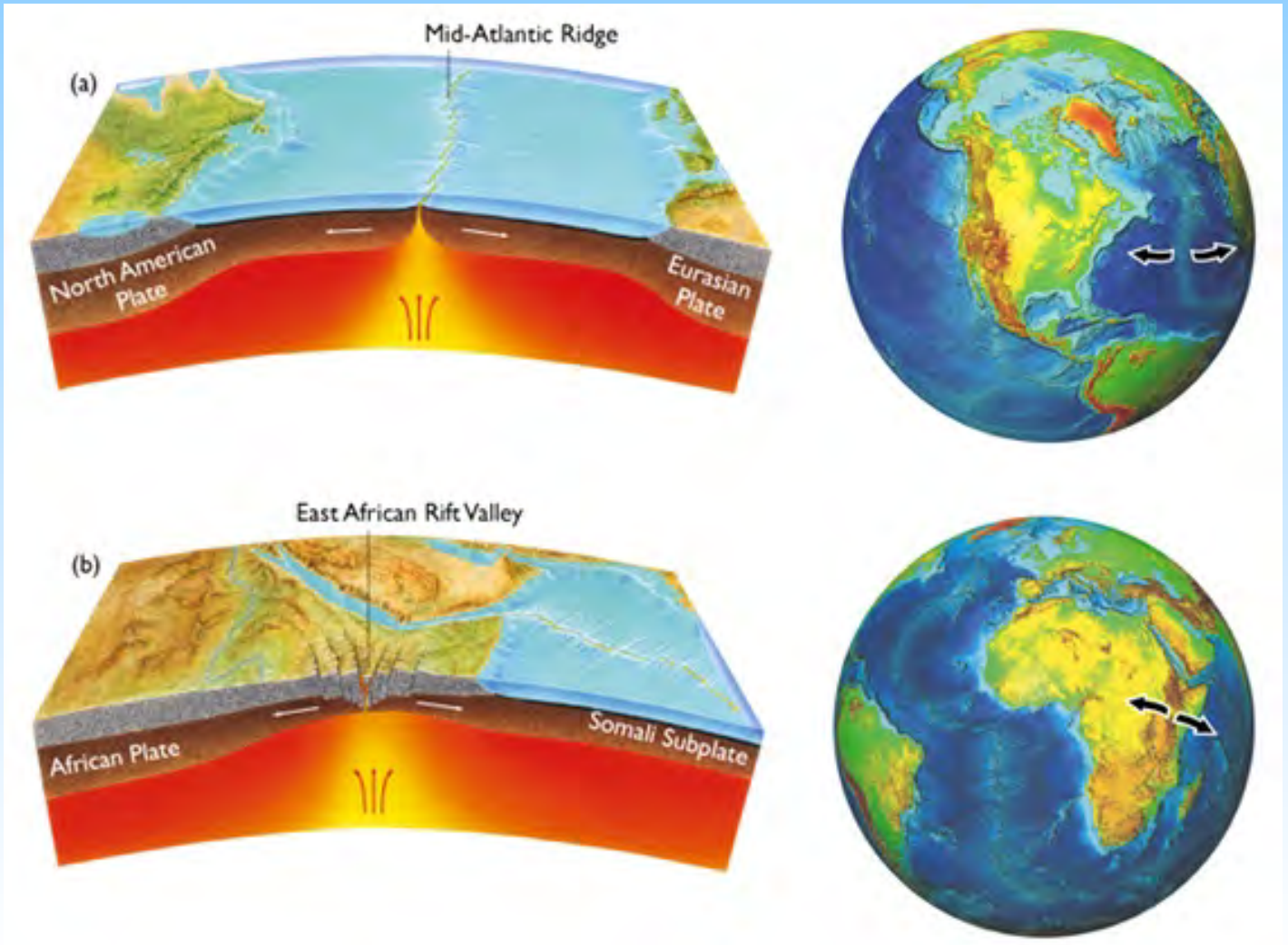
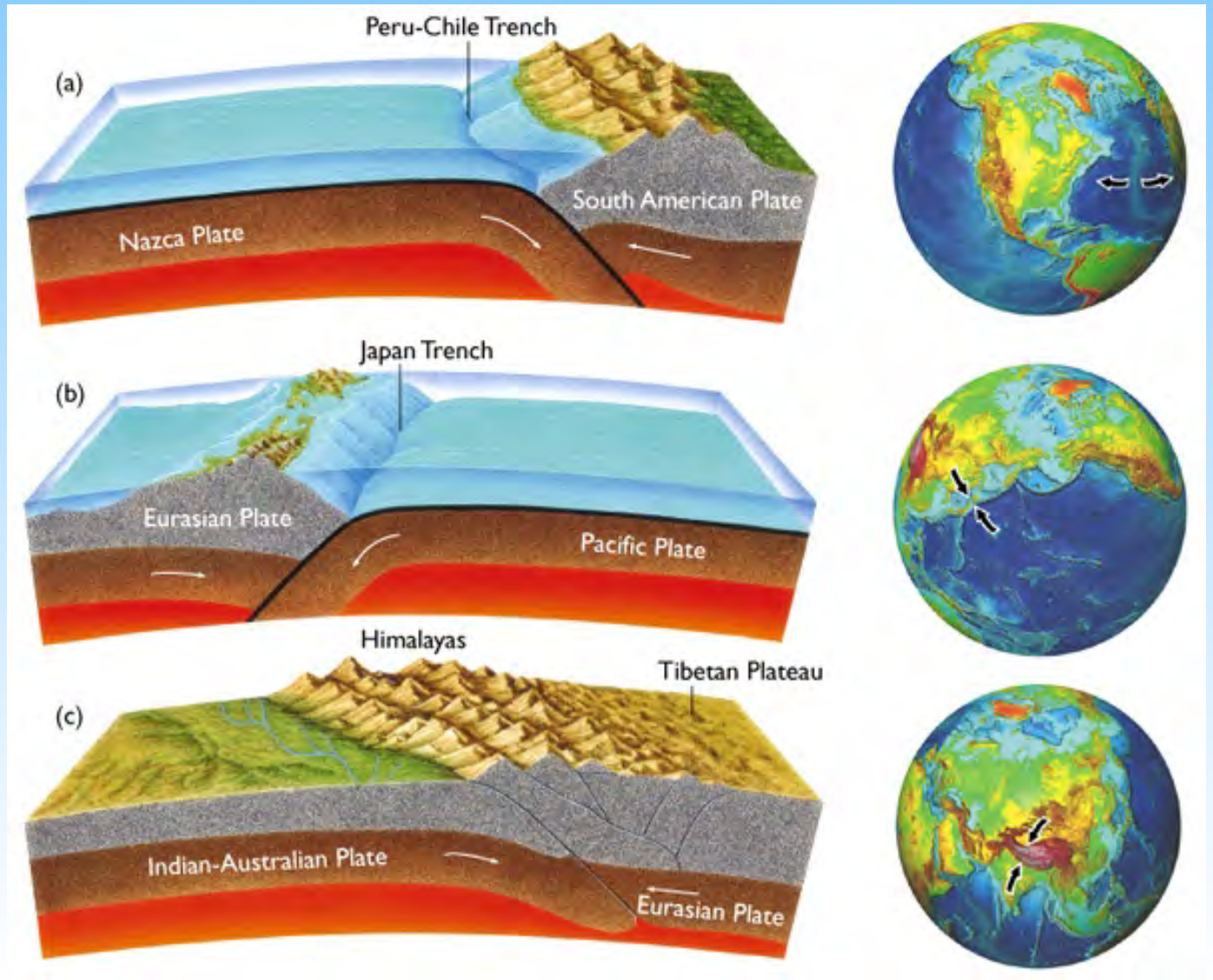


Plate tectonics

Convergent plate boundaries

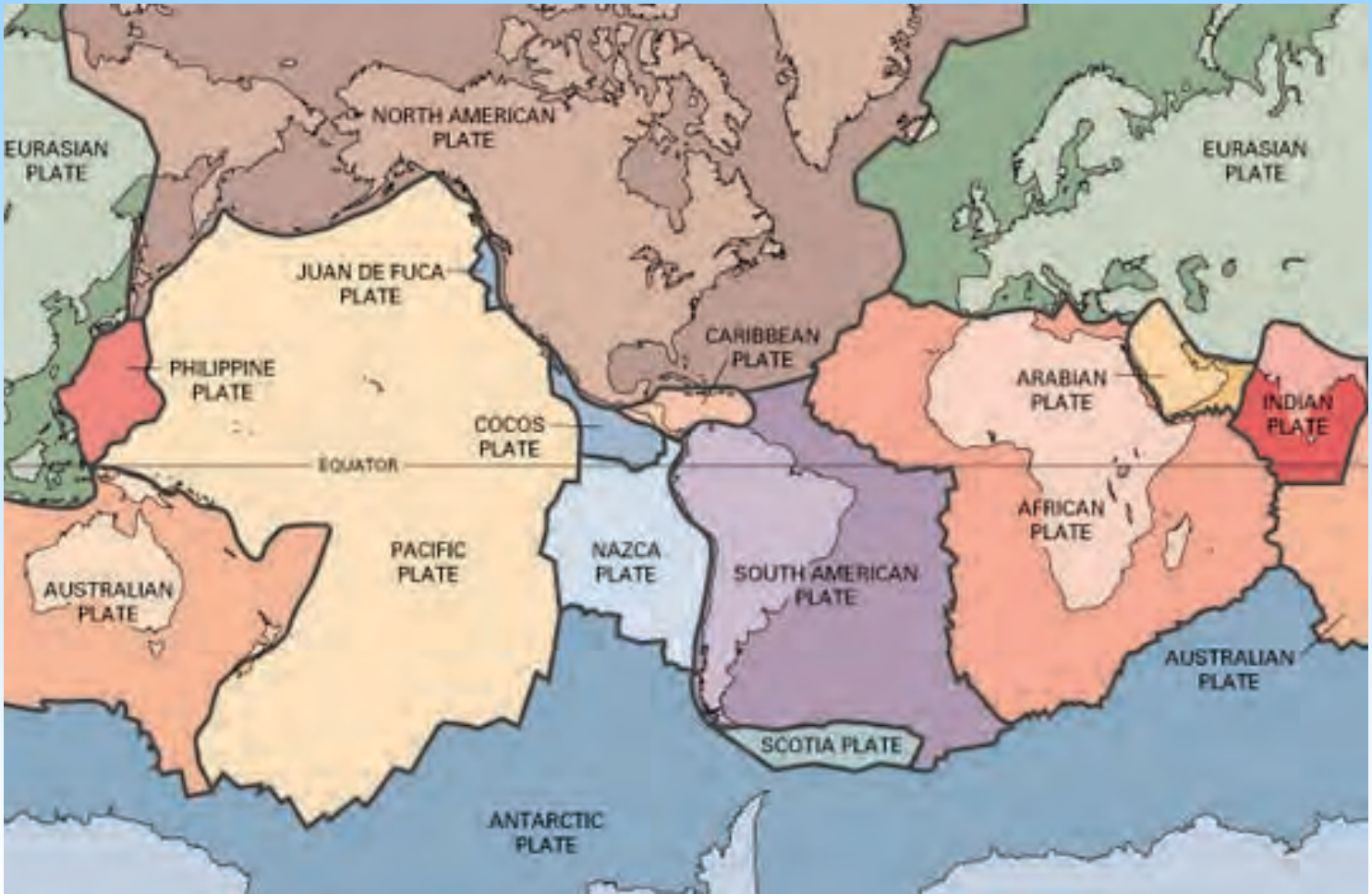


Geodynamic Processes at Rifting and Subducting Margins

GeoPRISMS

Plate tectonics

Some plates are all oceanic, others are part continental and part oceanic



Super continents:

Atlantic ocean

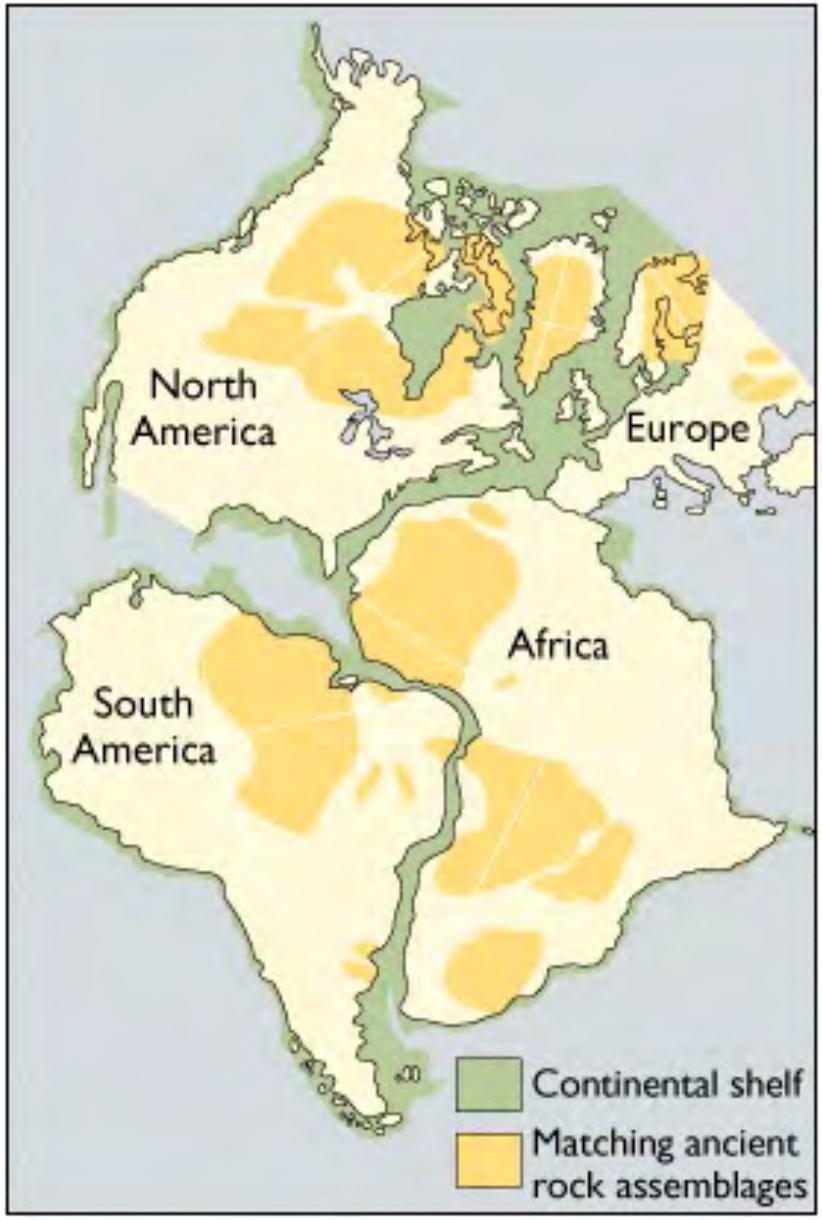
Pangea: 250-230 million yr

Iapetus ocean

Rodinia: 1100-750 million yr

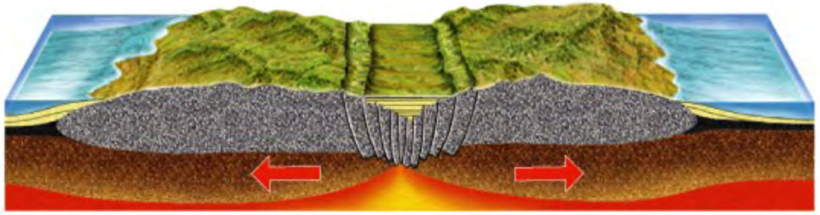
Nuna: 1800-1500 million yr

Oceans open and close.

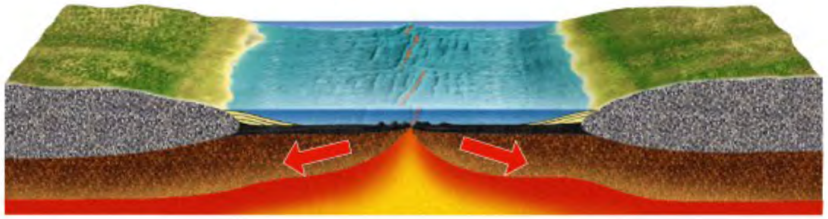


Alfred Wegener's idea (1911)

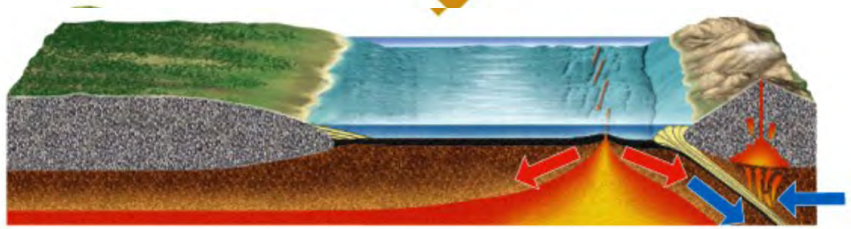
Wilson cycle:



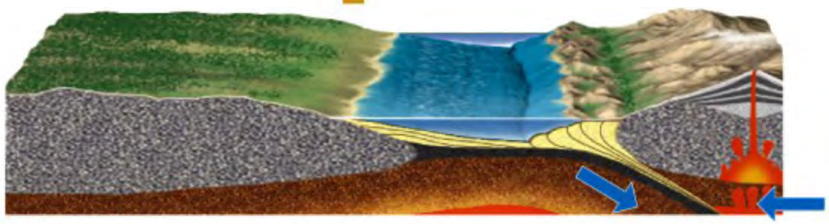
1 Rifting within a continent splits the continent,...



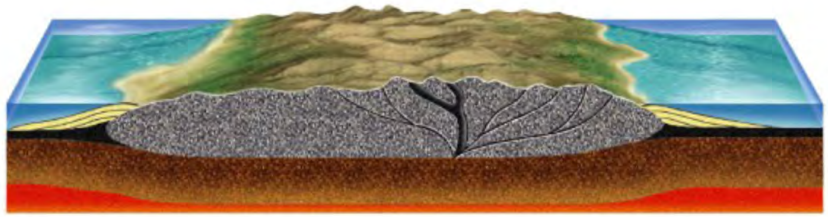
2 ...leading to the opening of a new ocean basin and creation of new oceanic crust, starting the cycle.



4 Convergence begins; oceanic crust is subducted beneath a continent, creating a volcanic mountain belt at the active margin.



5 Terrane accretion—from the sedimentary accretionary wedge or fragments carried by the subducting plate—welds material to the continent.



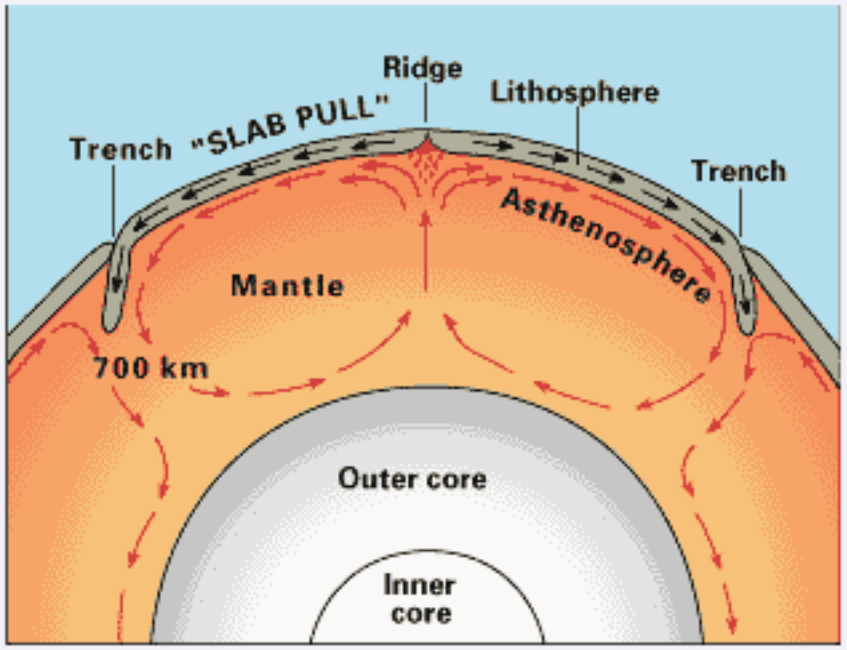
7 The continent erodes, thinning the crust. Eventually the process may begin again.

Mantle convection

Mantle turns over to remove the heat from the core.

Drag at the base of the plates can drive plate tectonics, including rifting and subduction.

Supercontinents form when there is little rifting for some millions of years.



Geodynamic Processes at Rifting and Subducting Margins

Mosaic of continents

Cratons

Mountain belts

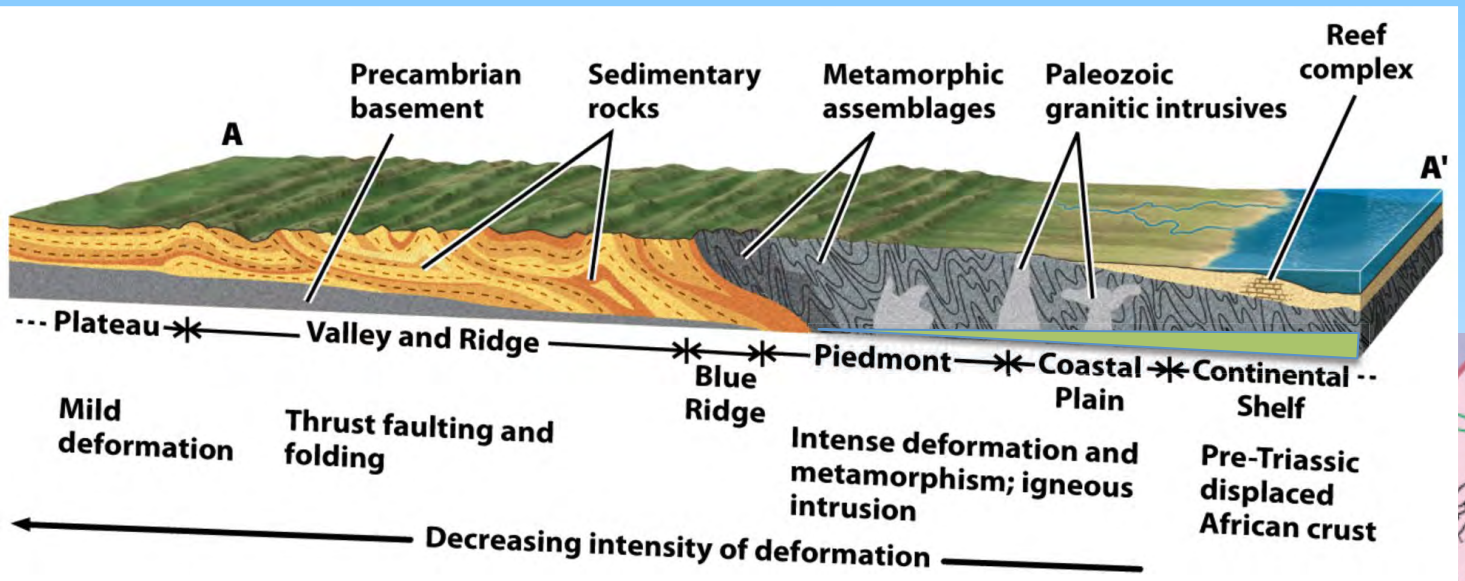
Coastal plains

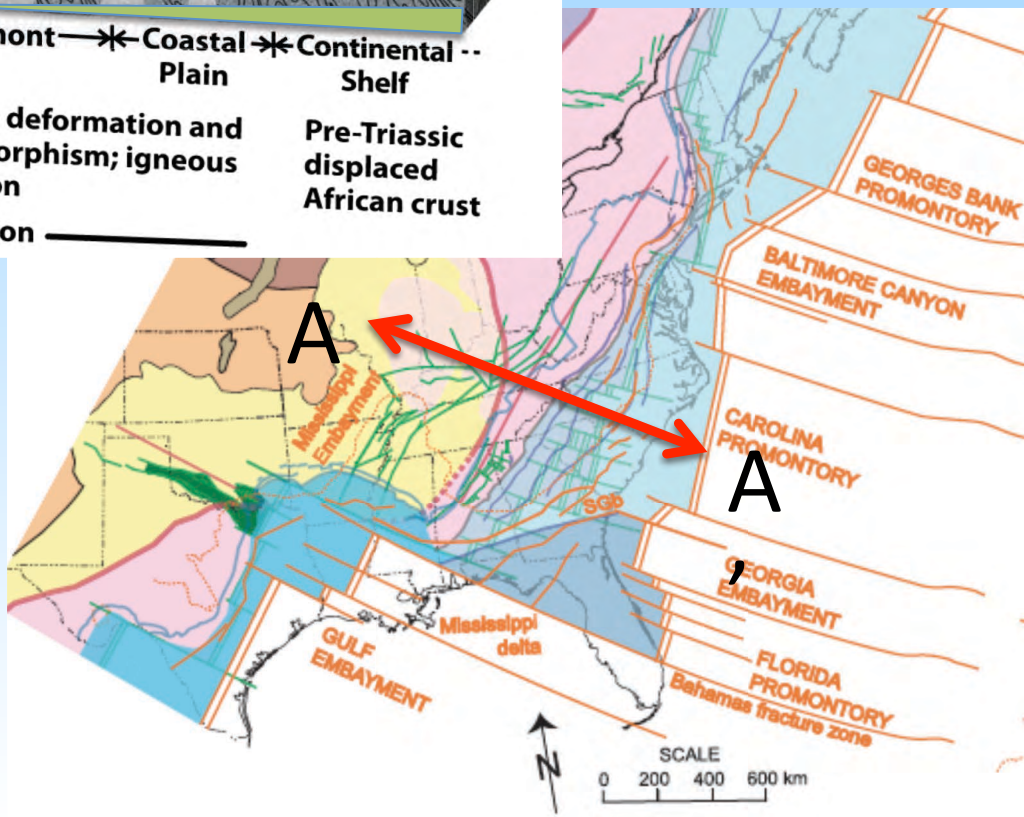
Oceans

Geodynamic Processes at Rifting and Subducting Margins

Wilson cycle

Appalachian terranes are bounded by sutures





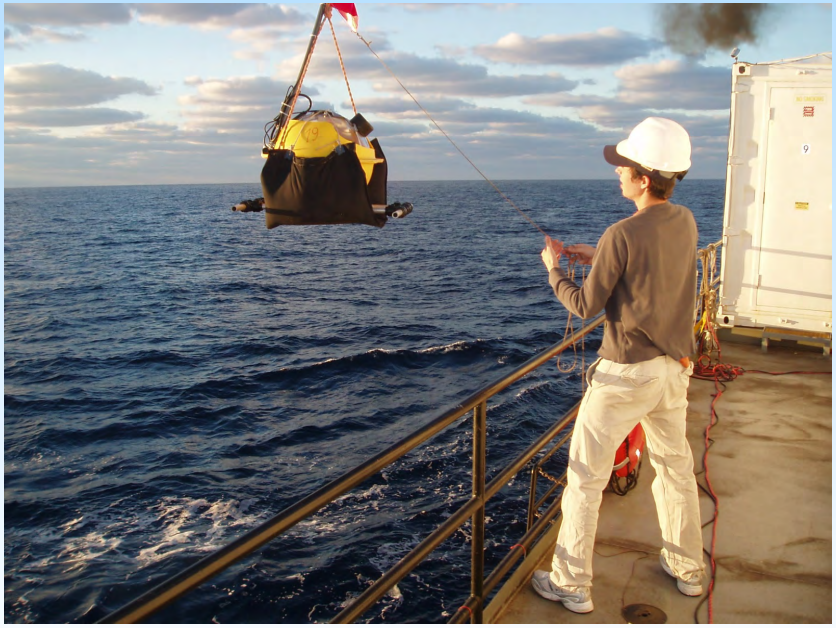
Breakup of Pangea was parallel to old terrane boundaries.

Thomas (GSA Today, 2006)

GeoPRISMS Geodynamic Processes at Rifting and Subducting Margins

Studies of continental margins

We use geophysical methods to study rifted margins that lie offshore beneath oceans and sediments.

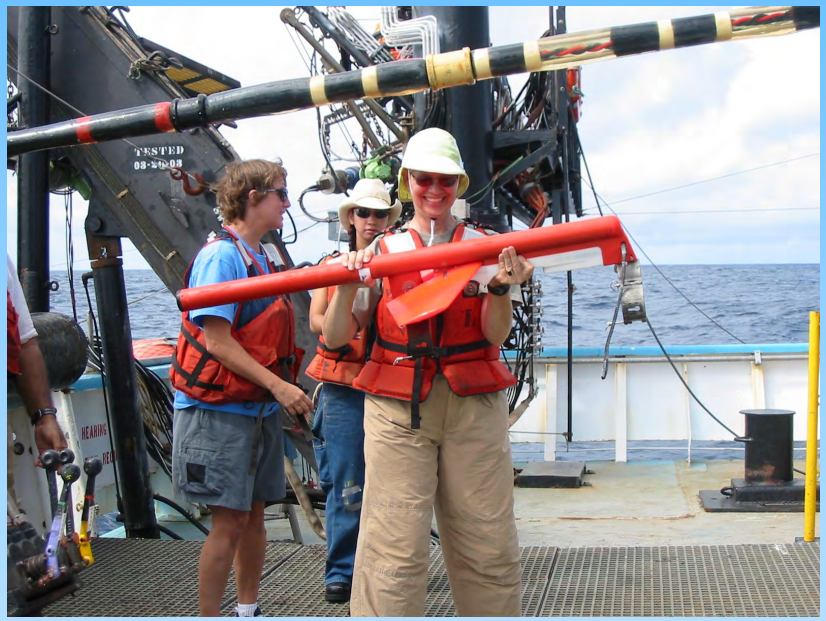


Geodynamic Processes at Rifting and Subducting Margins

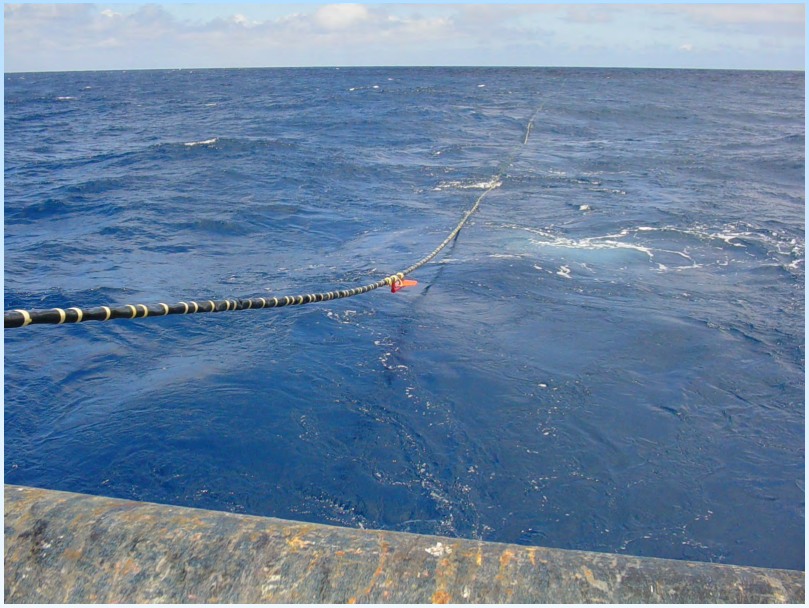
GeoPRISMS

Marine seismic data

Sea-going expeditions



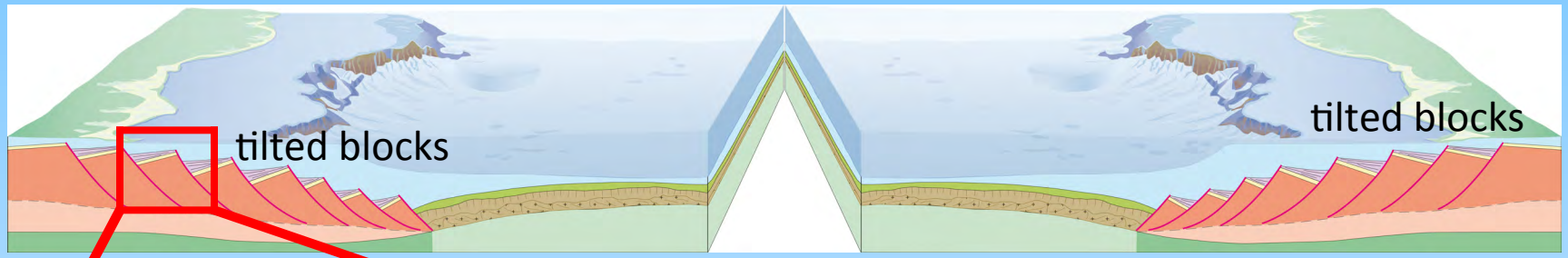
R/V Marcus Langseth

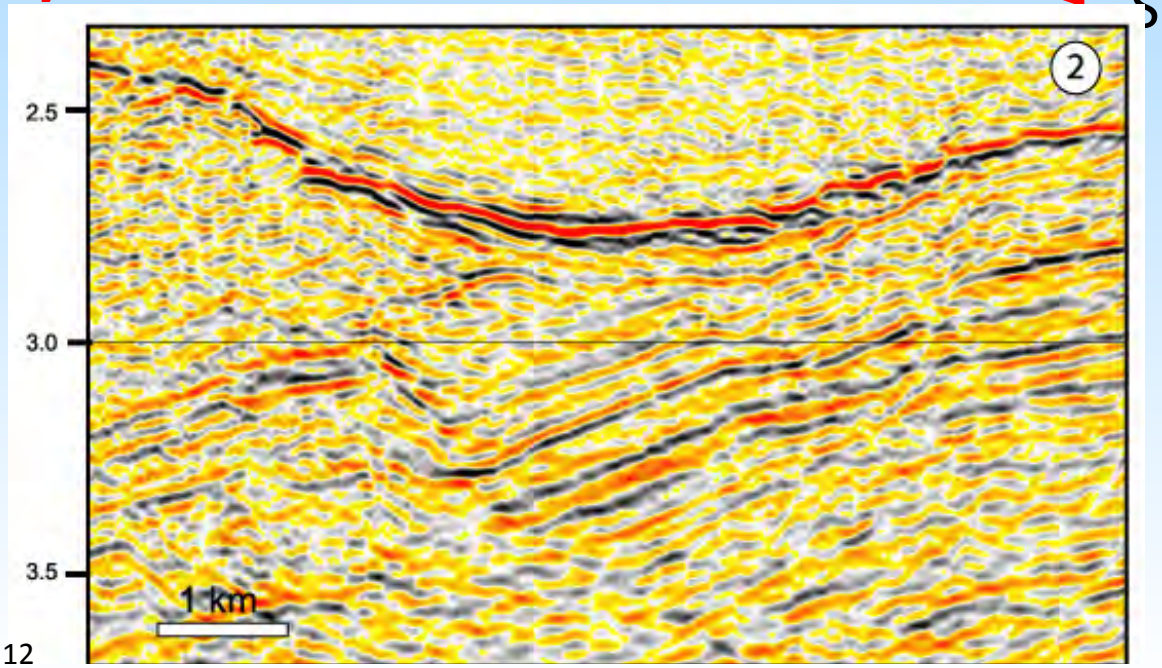


R/V Maurice Ewing

Geo PRISMS Geodynamic Processes at Rifting and Subducting Margins

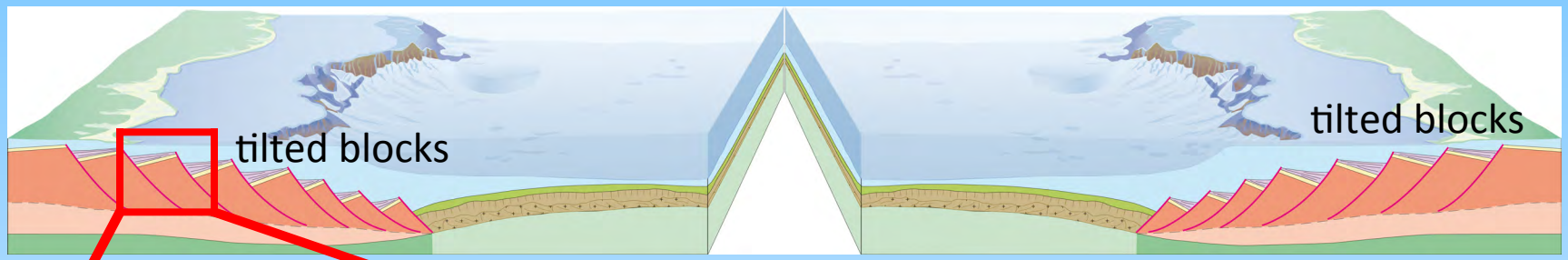
Seismic reflection data

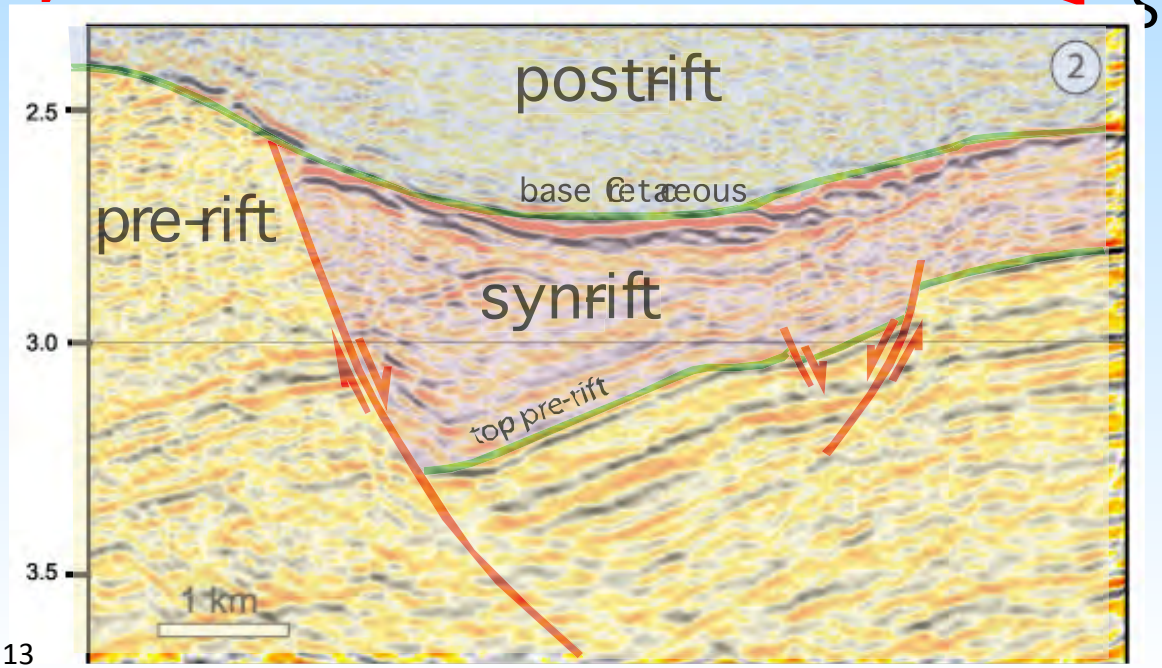




Seismic images of faults, blocks of continental crust, sediments that were deposited during and after the opening of the Atlantic Ocean.

Seismic reflection data

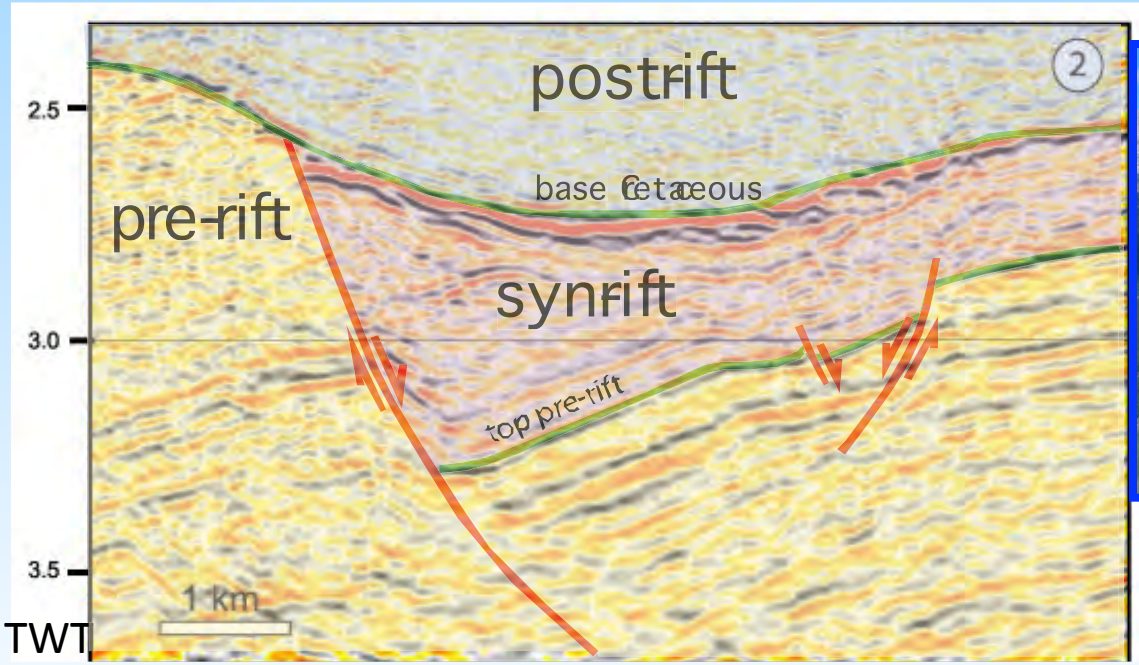




Seismic images of faults, blocks of continental crust, sediments that were deposited during and after the opening of the Atlantic Ocean.

We see the same structures in mountain belts (Alps) and continental margins

Offshore seismic image



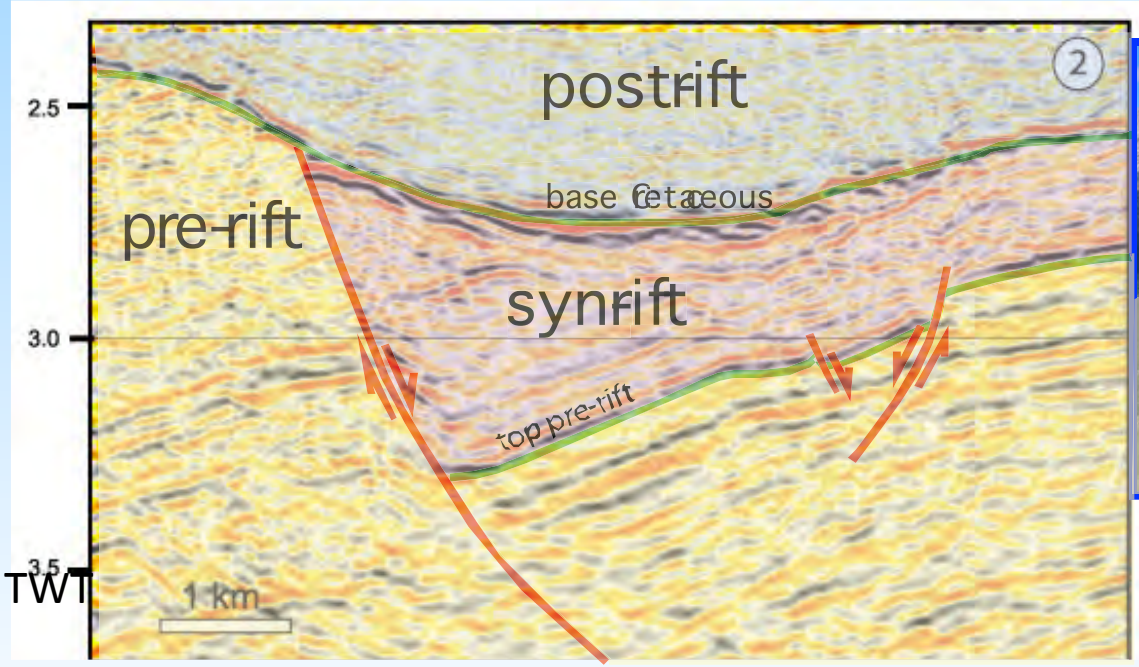
North Sea: from P.Covie (2004)

Onshore geology

Il Motto/Ortler nappe: Manatschal et al. (2007)

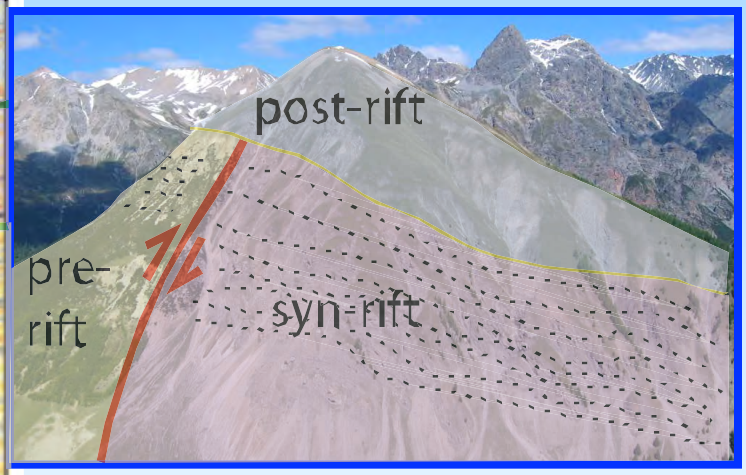
We see the same structures in mountain belts (Alps) and continental margins

Offshore seismic image



North Sea: from P.Covie (2004)

Onshore geology

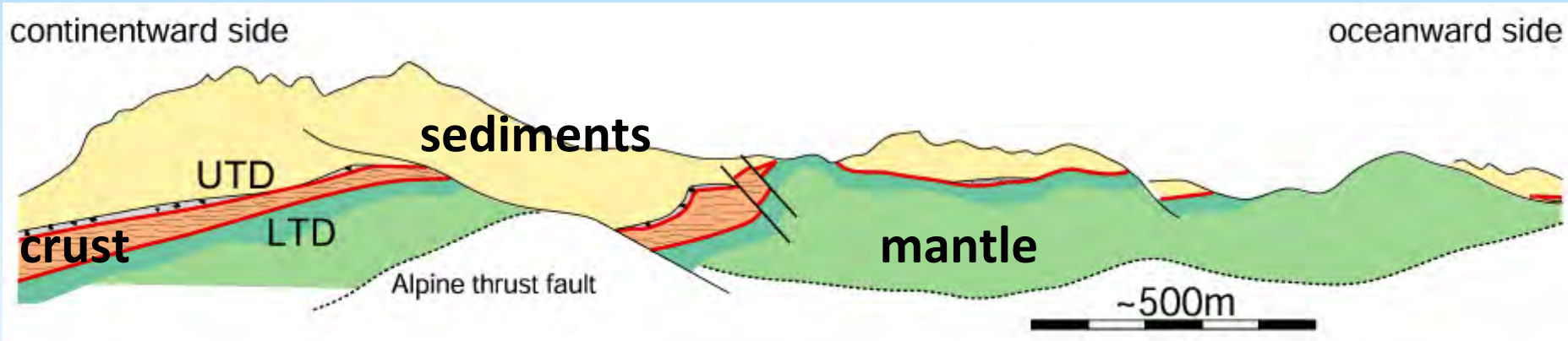


Il Motto/Ortler nappe: Manatschal et al. (2007)

Geodynamic Processes at Rifting and Subducting Margins

A wider view of the Alps

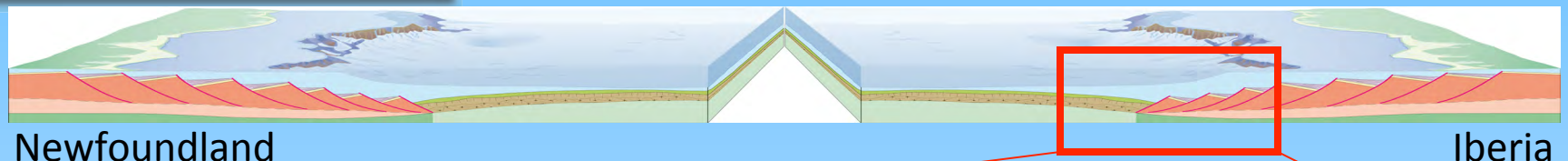
Tasna: Ocean-continent transition exposed in the Alps



Florineth and Froitzheim 1994, Manatschal et al. 2007

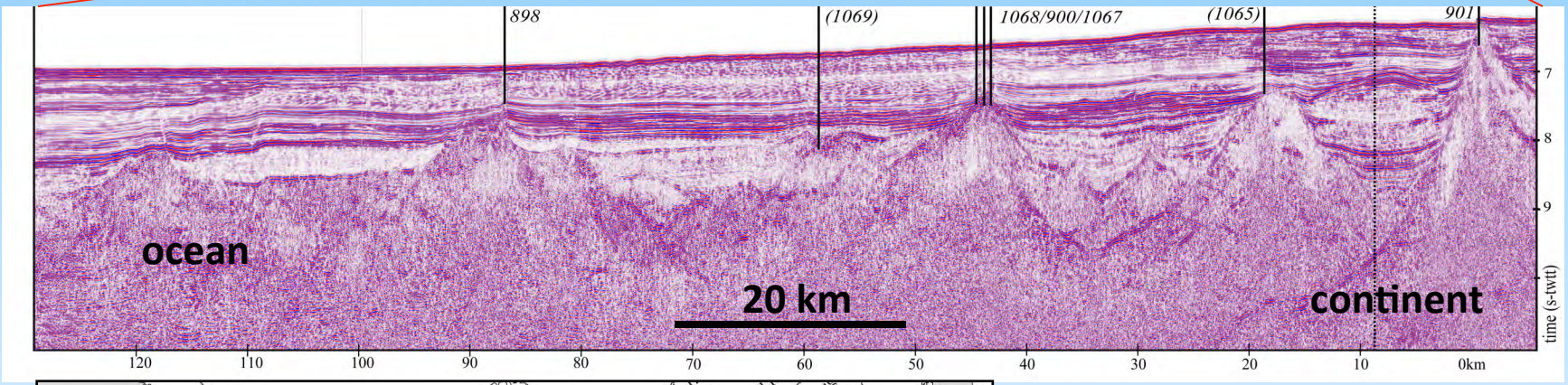
Geodynamic Processes at Rifting and Subducting Margins

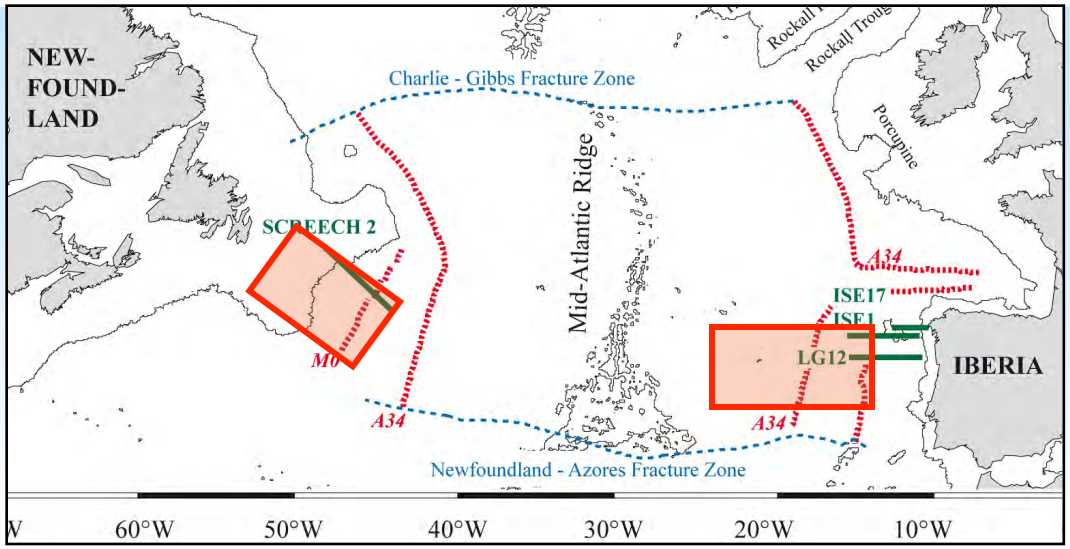
Seismic studies across the margin



Newfoundland

Iberia

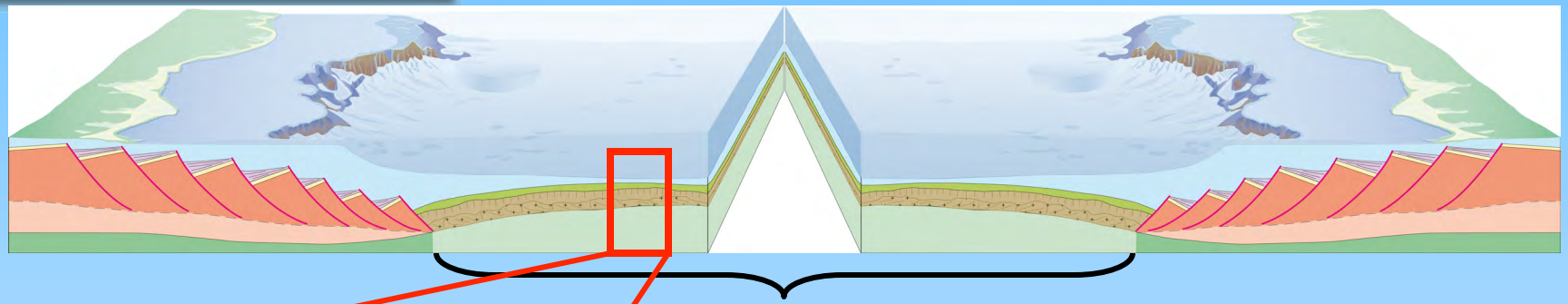


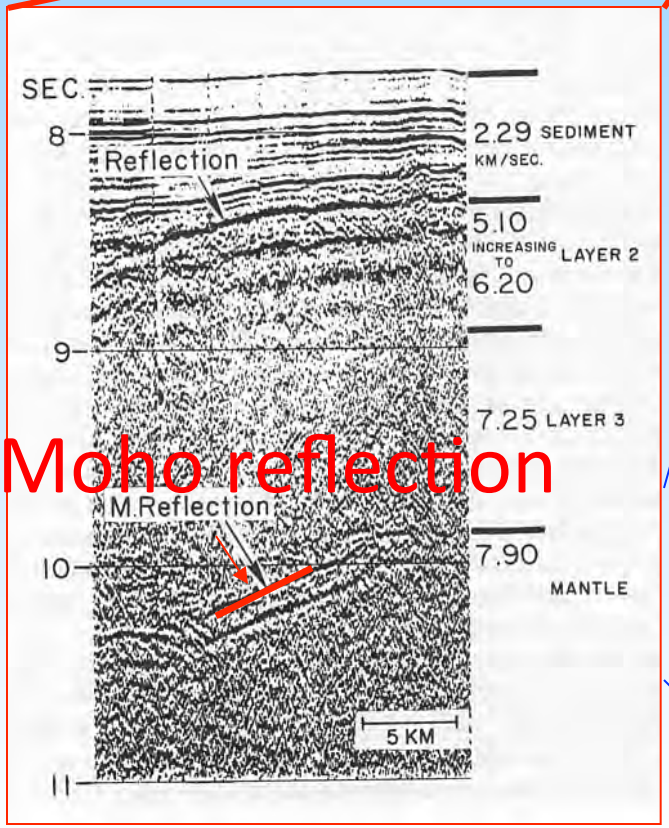


Geodynamic Processes at Rifting and Subducting Margins

GeoPRISMS

The oceanic crust





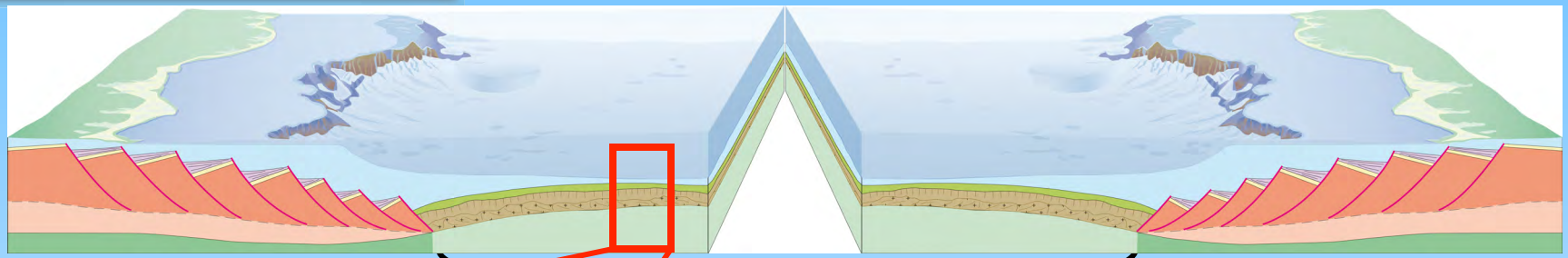
Crust-mantle boundary in Oman

Oman: from Nicolas, Boudier)

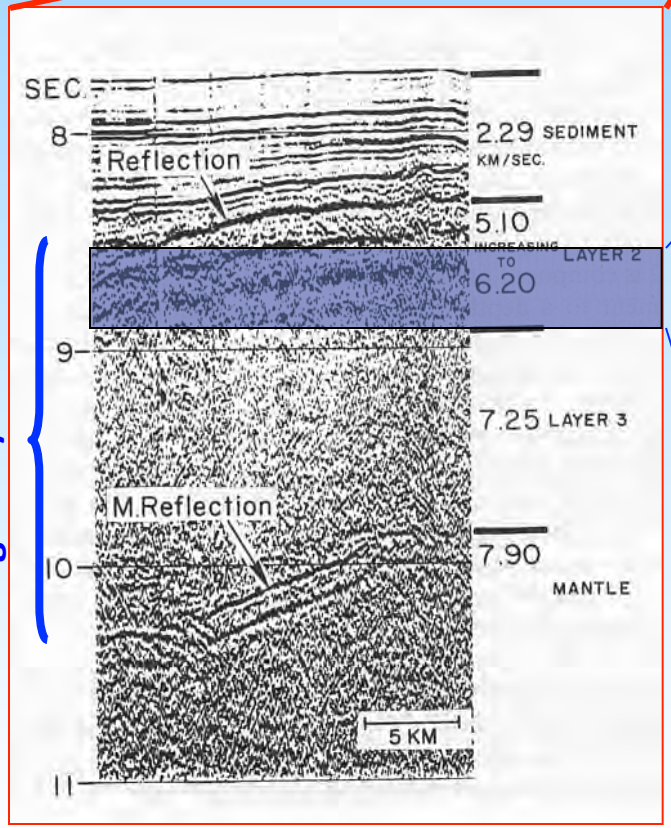
Geodynamic Processes at Rifting and Subducting Margins

GeoPRISMS

The oceanic crust



Oceanic crust

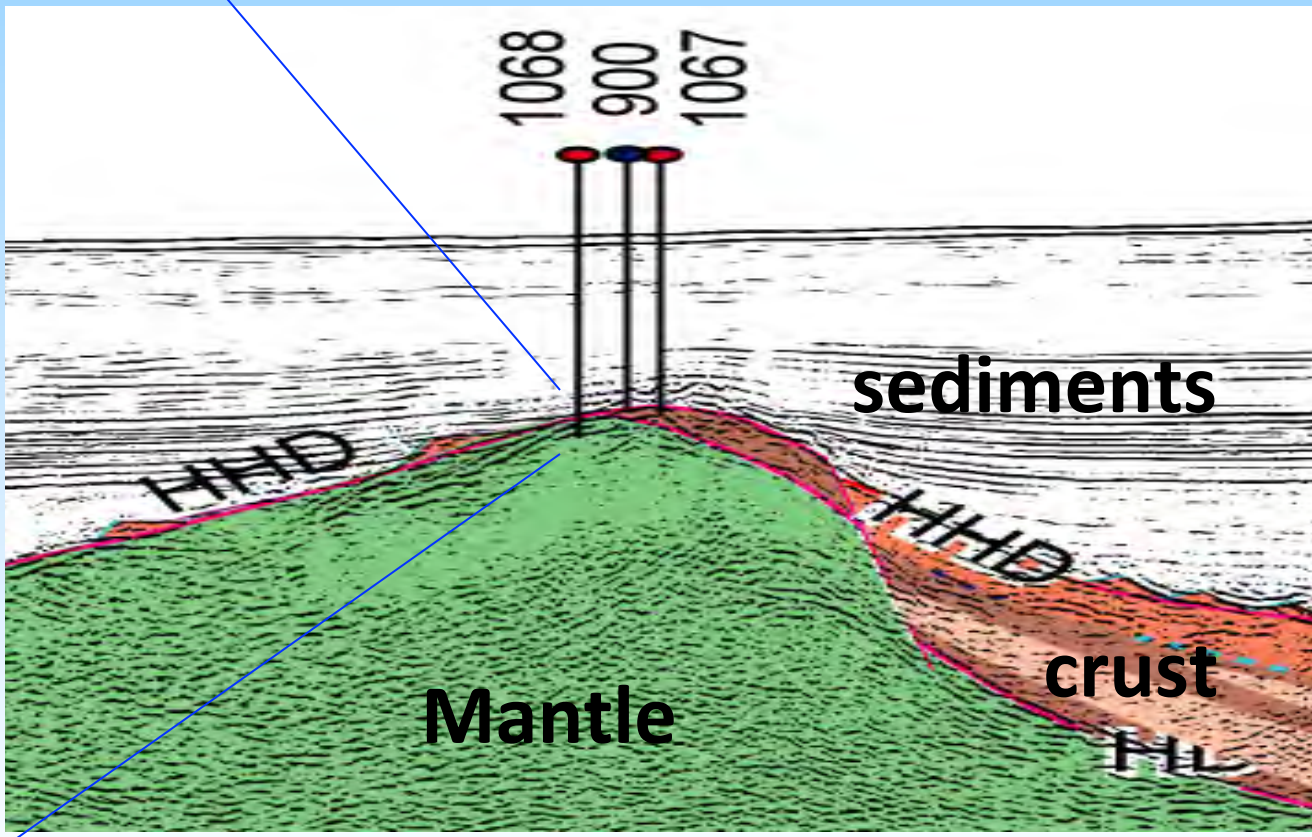


magmatic/mafic crust

Shallow ocean crust: Sheeted dikes

Geodynamic Processes at Rifting and Subducting Margins

Ocean Drilling Program



Lusigal 12 reflection seismic section

Debris flows

Tectono/sedi-mentary breccia

Tectonized mantle

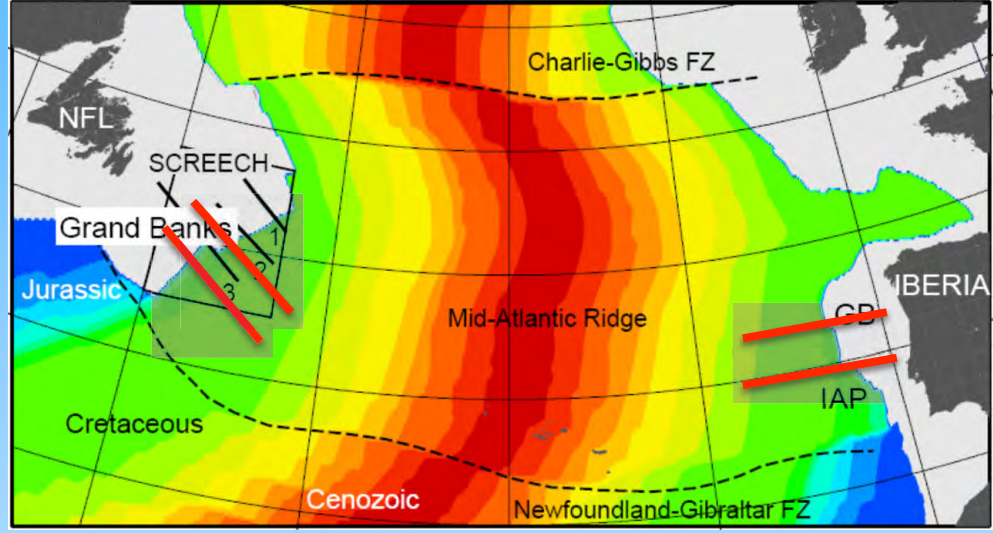
Serpentinized mantle

Geodynamic Processes at Rifting and Subducting Margins

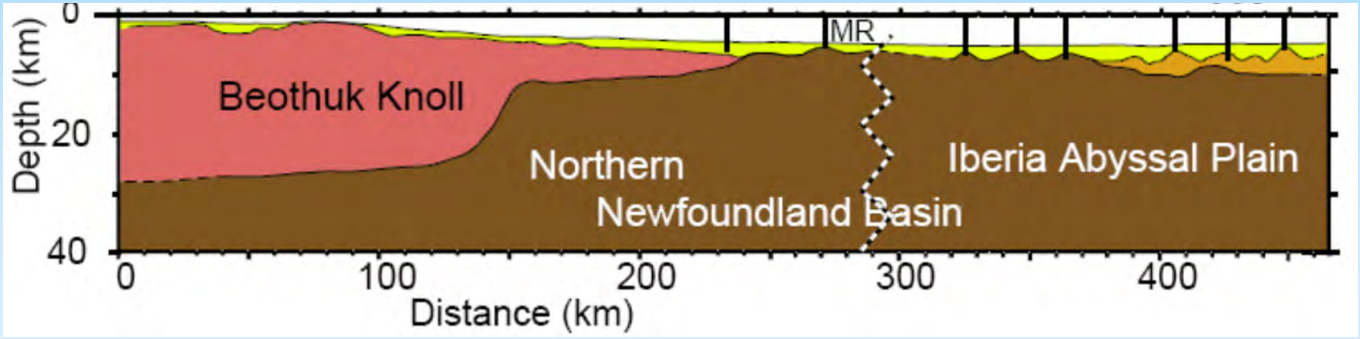
GeoPRISMS

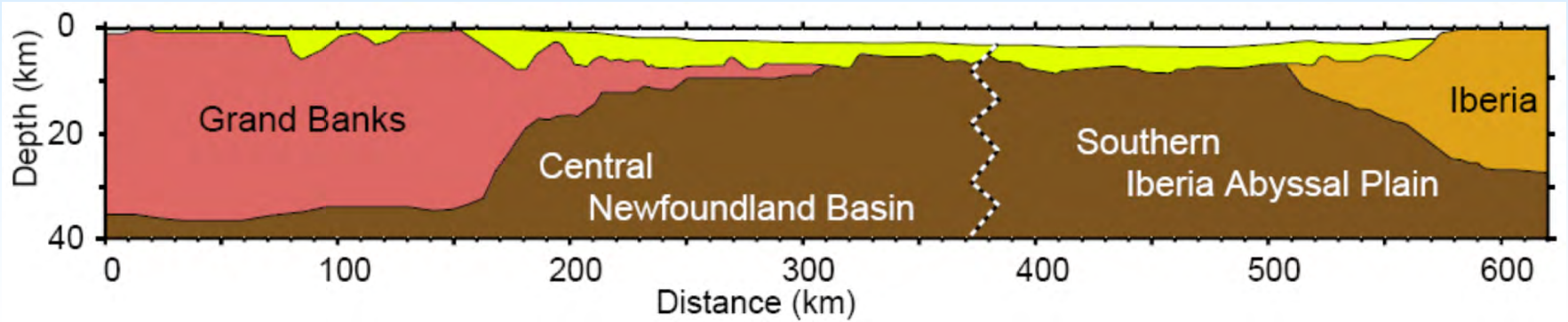
Seismic profiles:

Crustal thickness variations give us a record of stretching and continental breakup

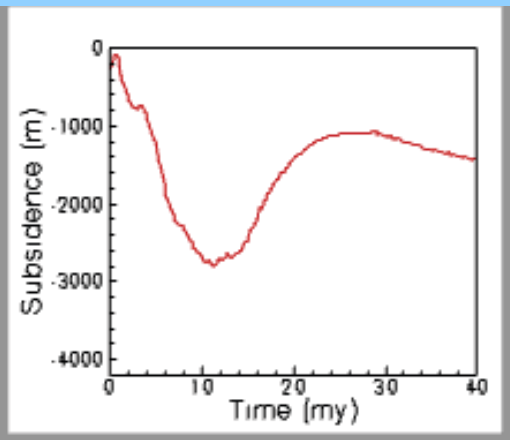


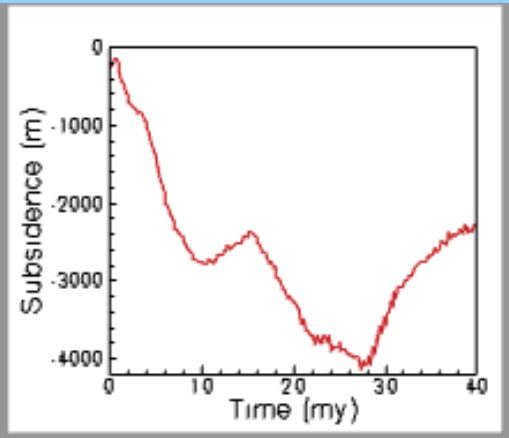
Map of Canadian and West-European margins

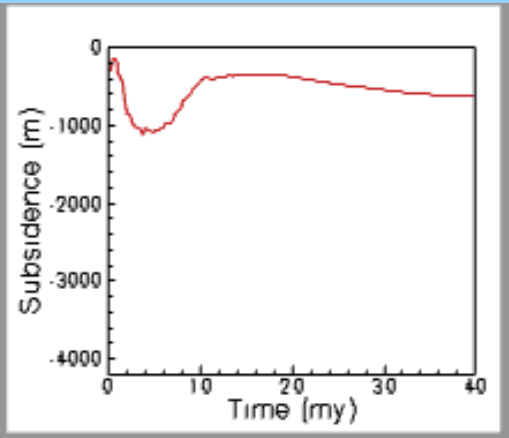


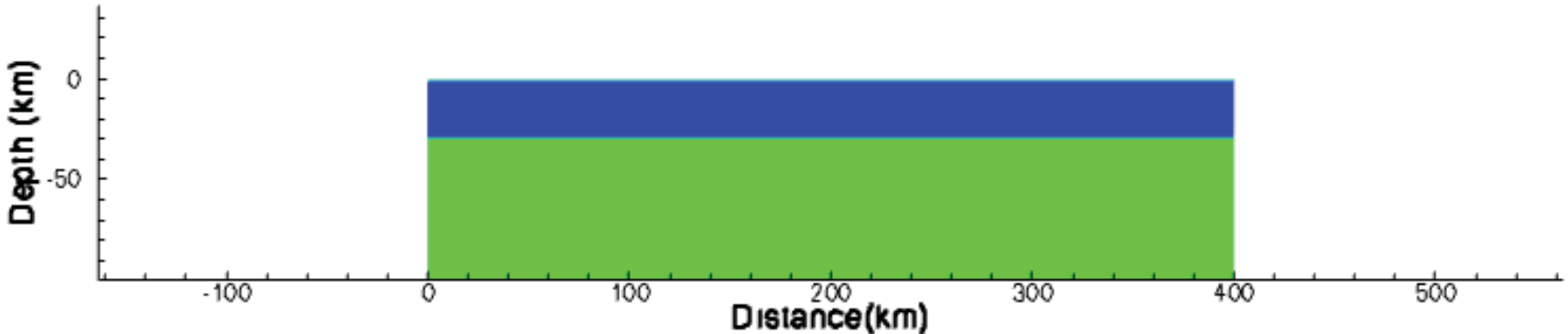


Computer animation of continental breakup:





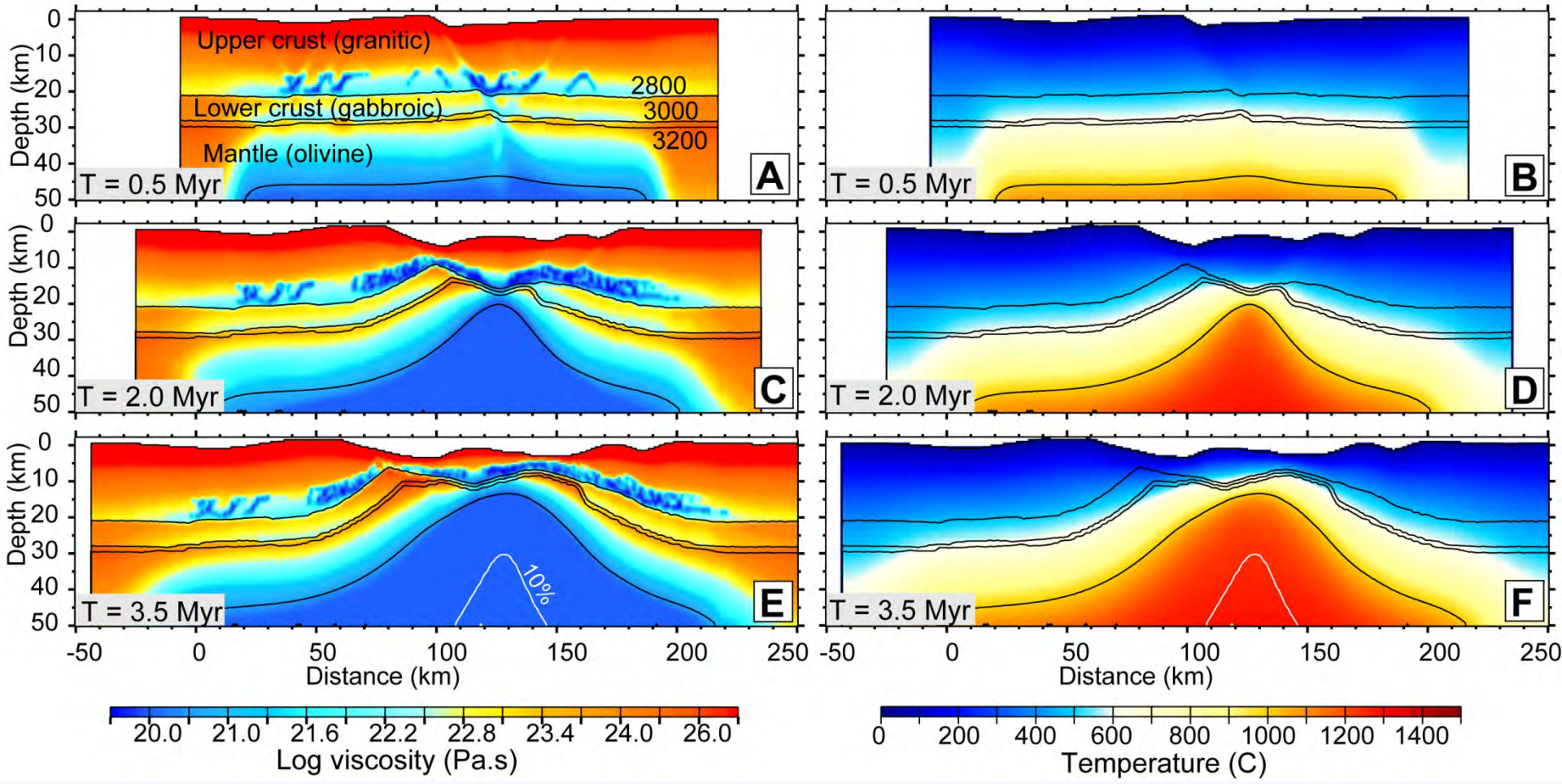




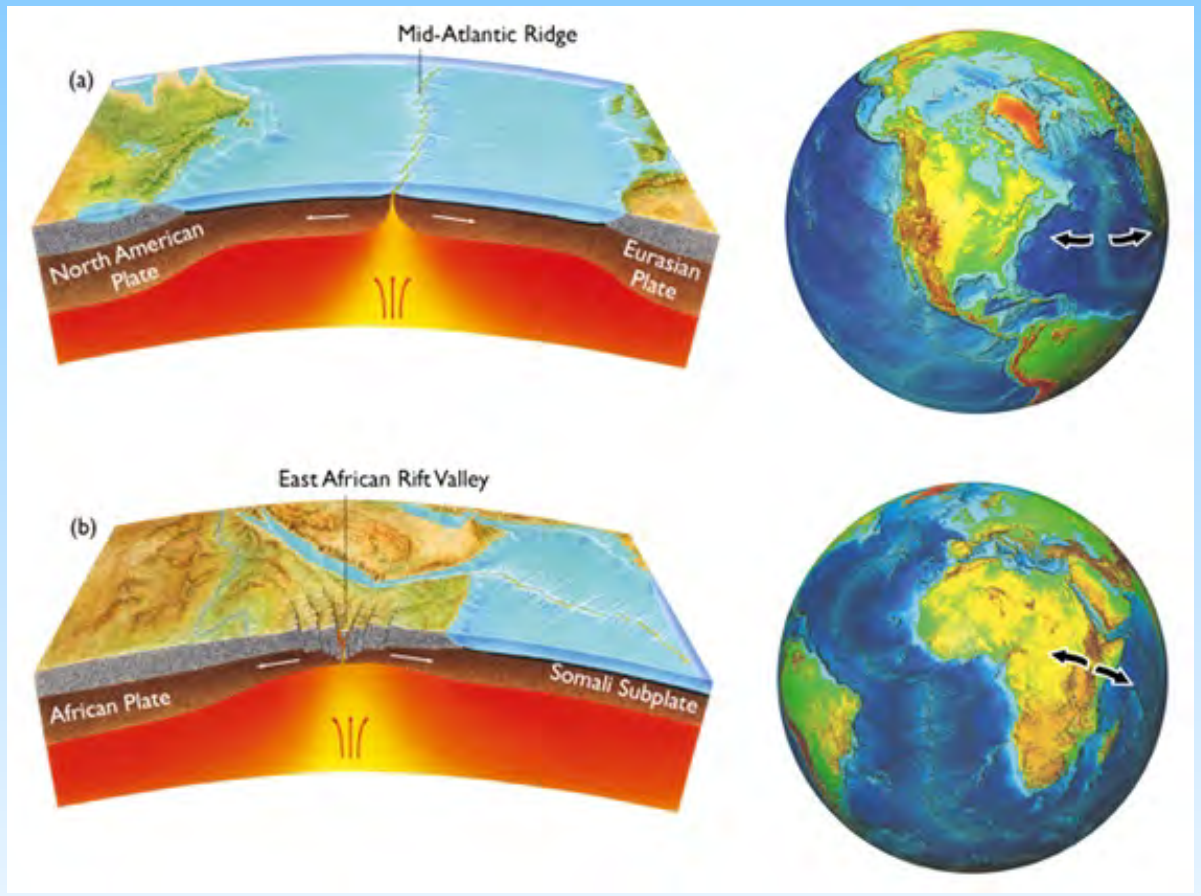
Geodynamic Processes at Rifting and Subducting Margins

GeoPRISMS

Computer model of continental breakup:

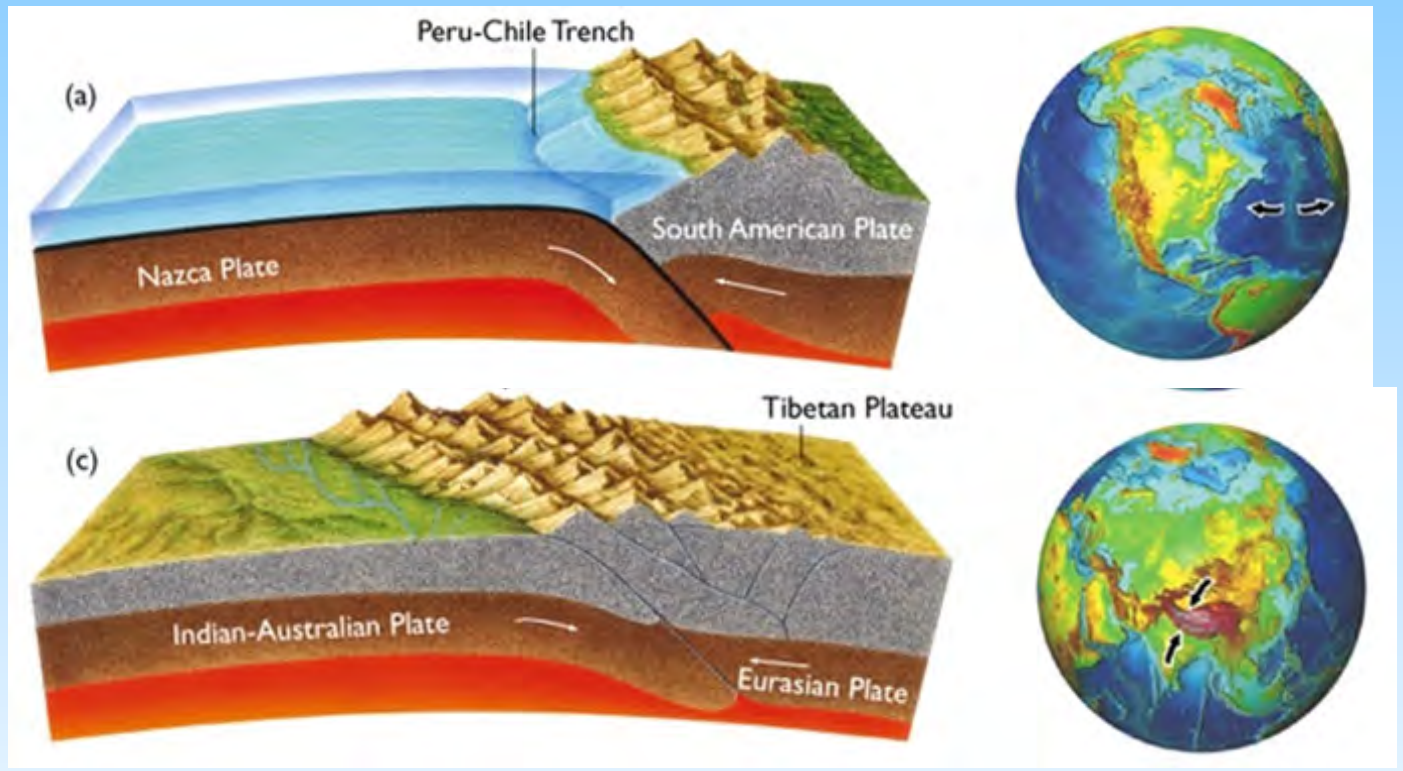


Continental rifting to seafloor spreading

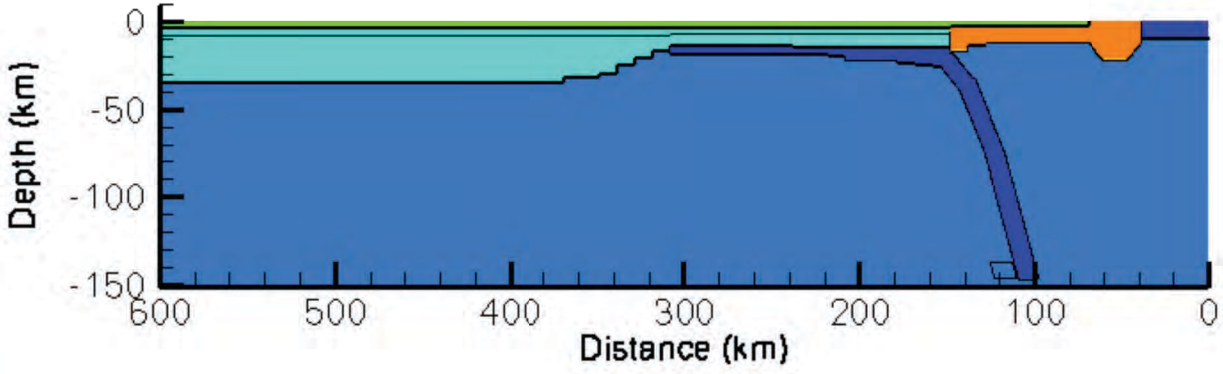


Continental plates are stretched and faulted at the margins during extension.

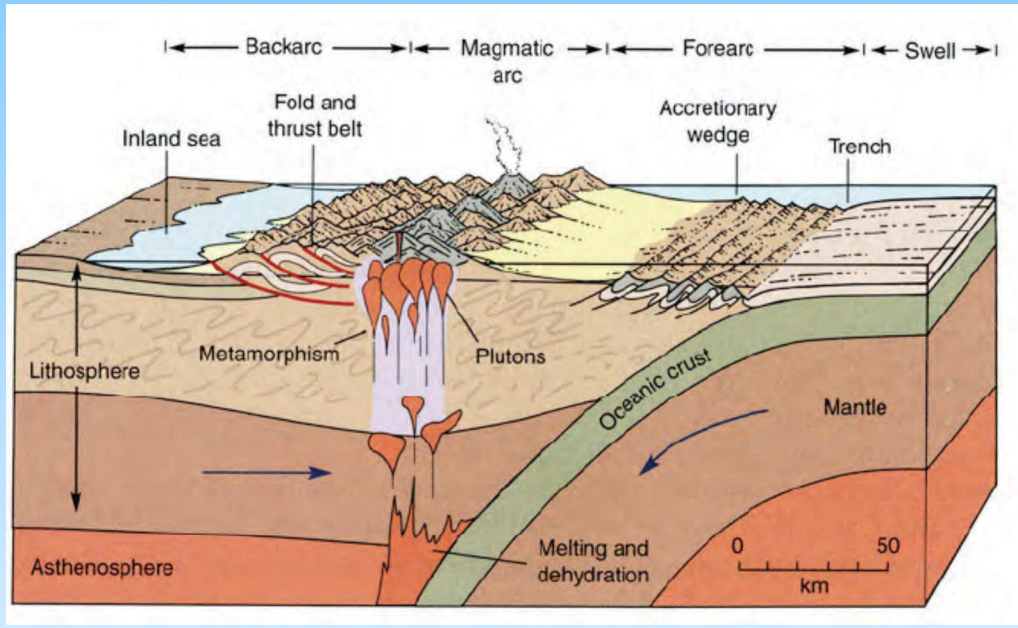
Subduction of seafloor to continental collision



Collision animation

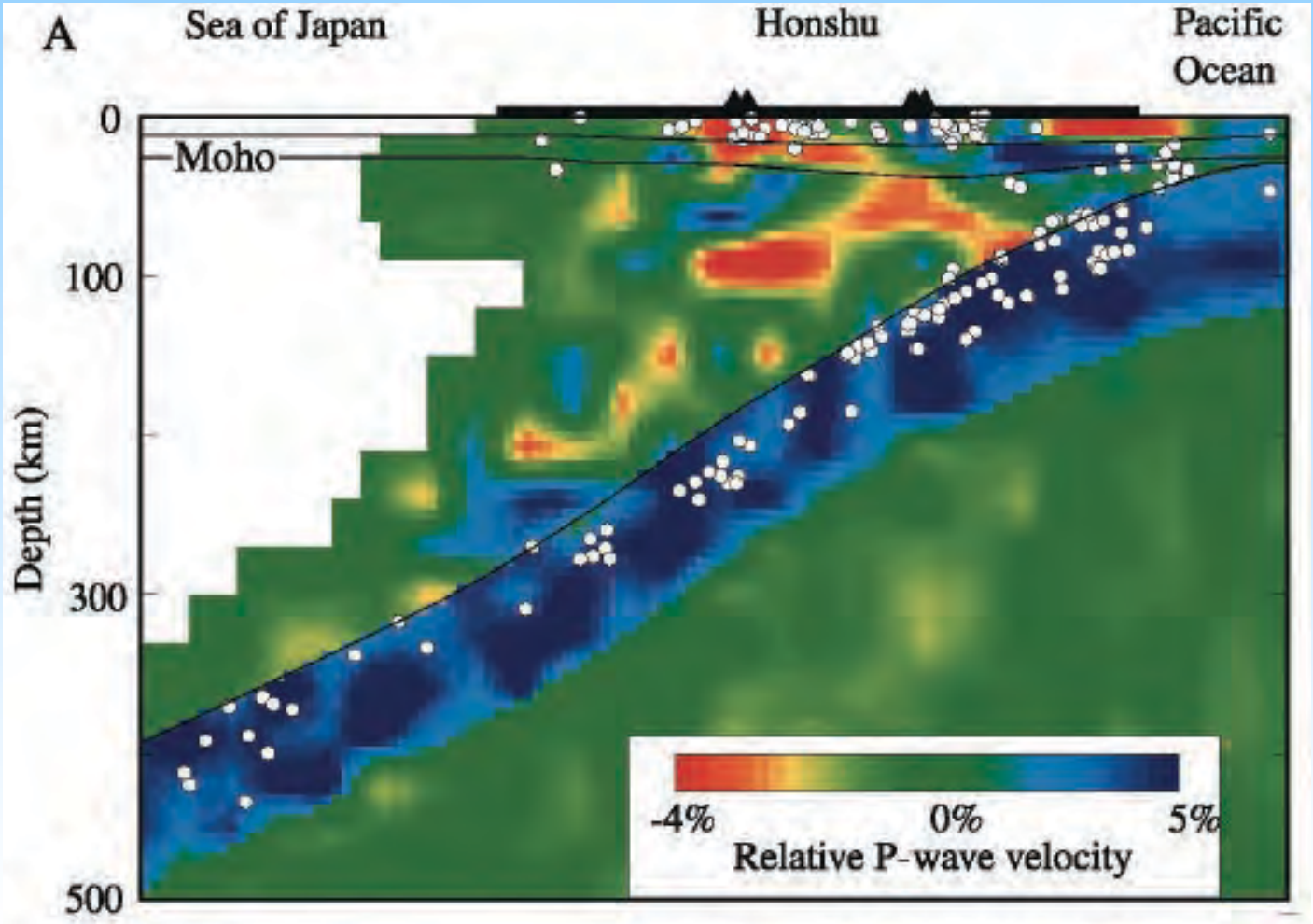


Exchange of water, CO2 at subduction zones



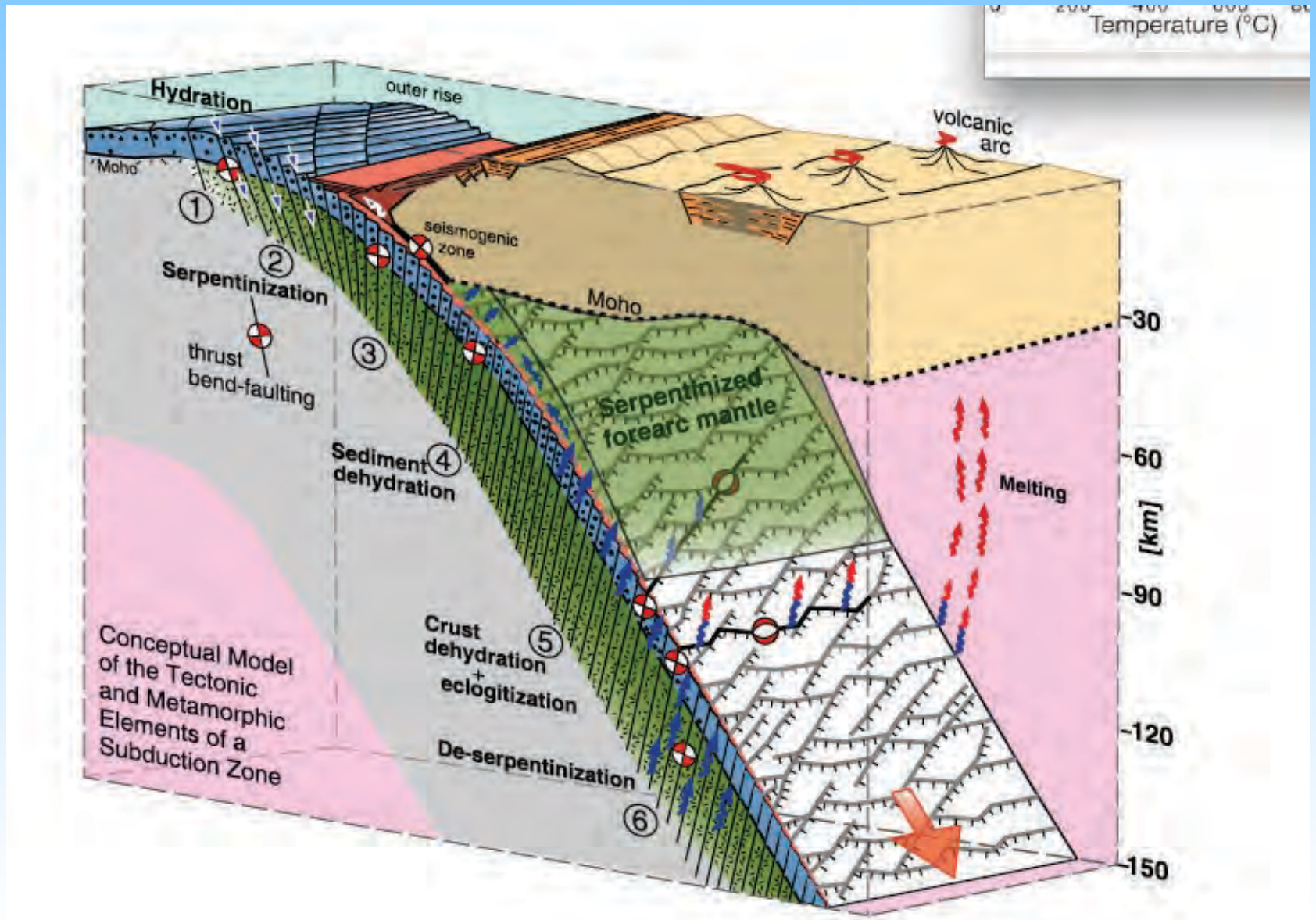
Volcanoes release fluids and gases that have traveled from the subducting plate through the mantle wedge, into the atmosphere

Evidence from seismology for subduction of oceanic plates

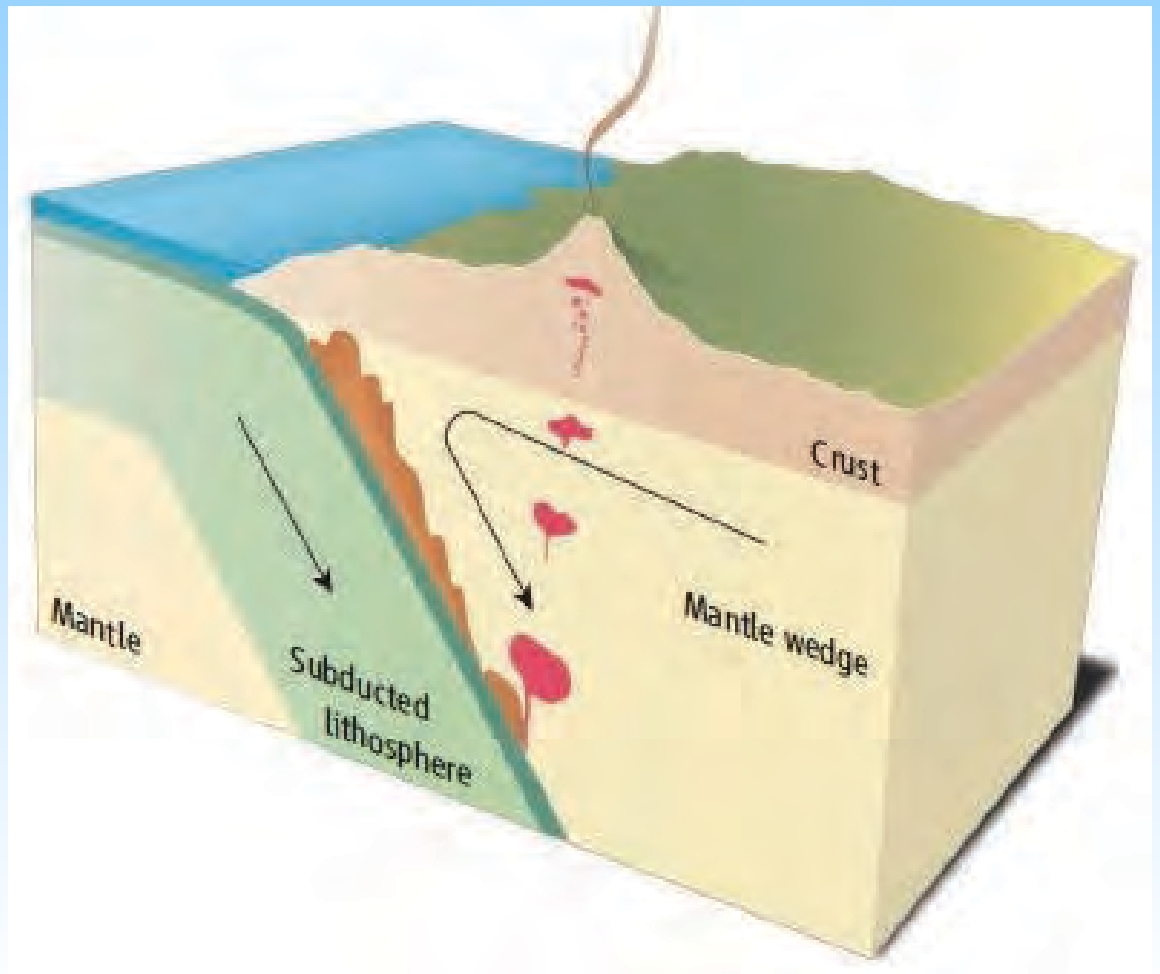


Geodynamic Processes at Rifting and Subducting Margins

Faulting and bending of a subducting ocean plate



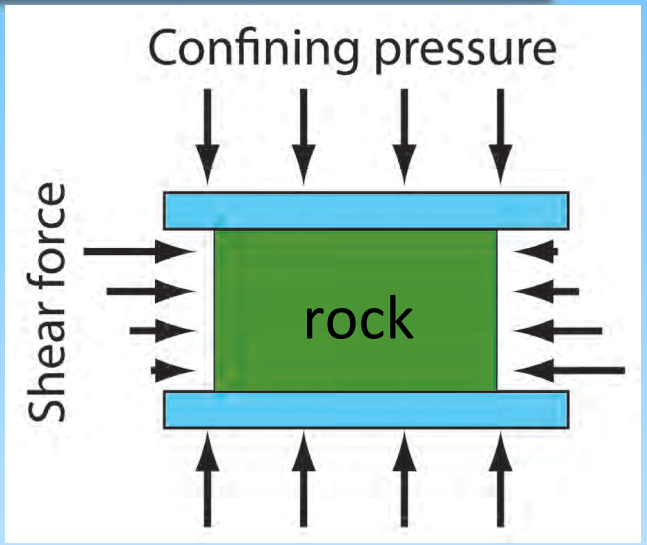
Water and melt transfers from downgoing oceanic plate to the mantle wedge.



Geodynamic Processes at Rifting and Subducting Margins

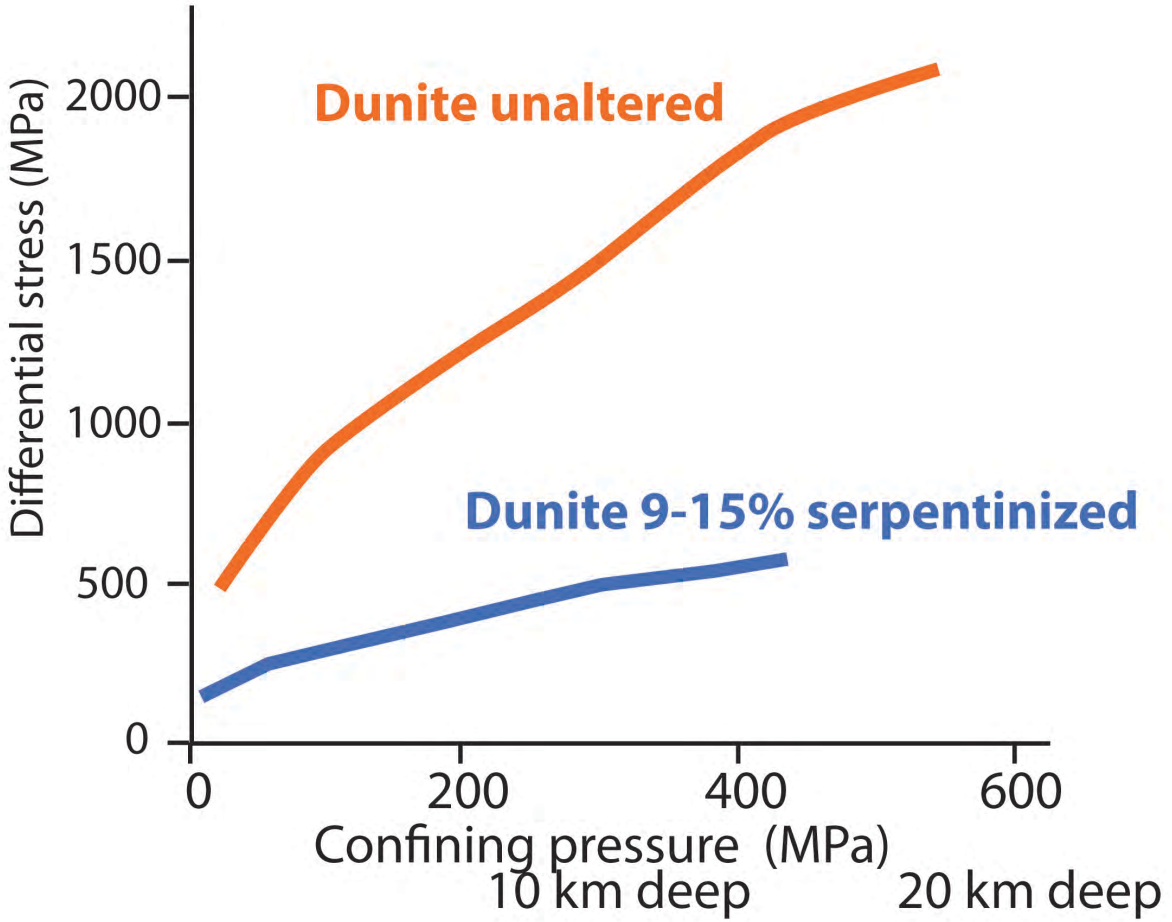
The strength of mantle rocks

Dunite is more difficult to break than serpentinite



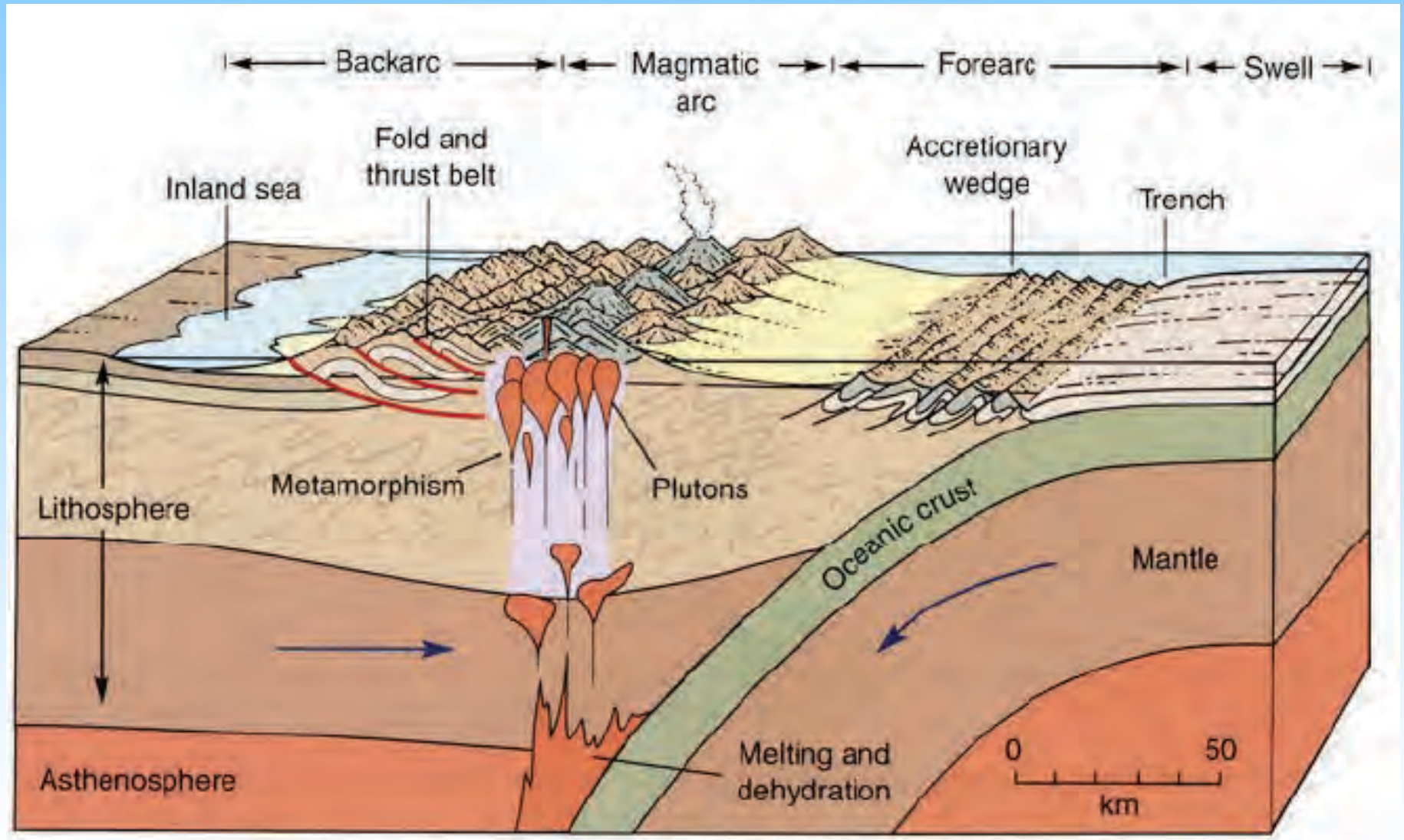
Serpentinite forms when water reacts with mantle dunite:

Maximum differential stress for serpentinized and unaltered mantle rock

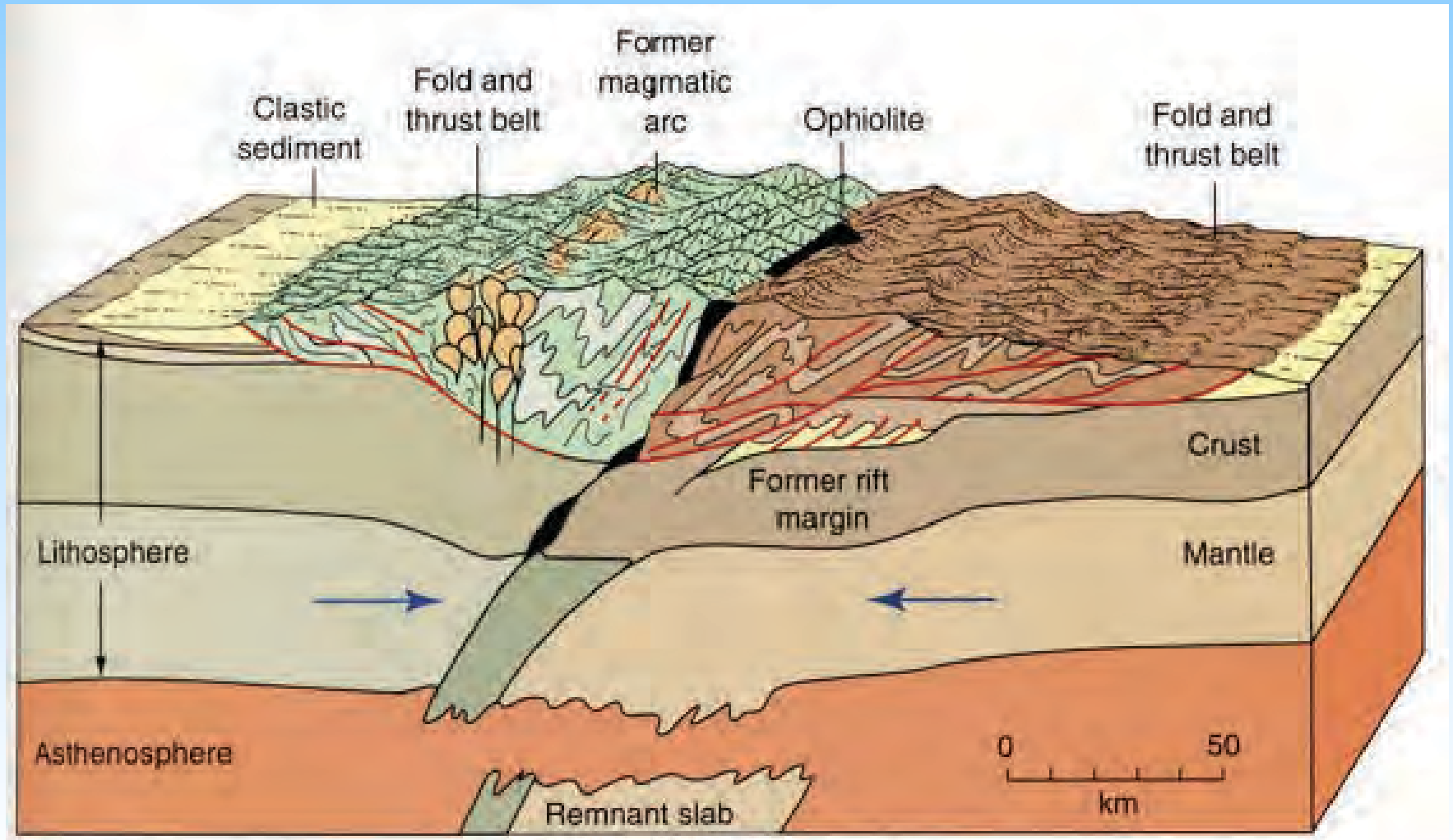


Escartin et al. (Geology, 2001)

Subduction zone with wet mantle wedge

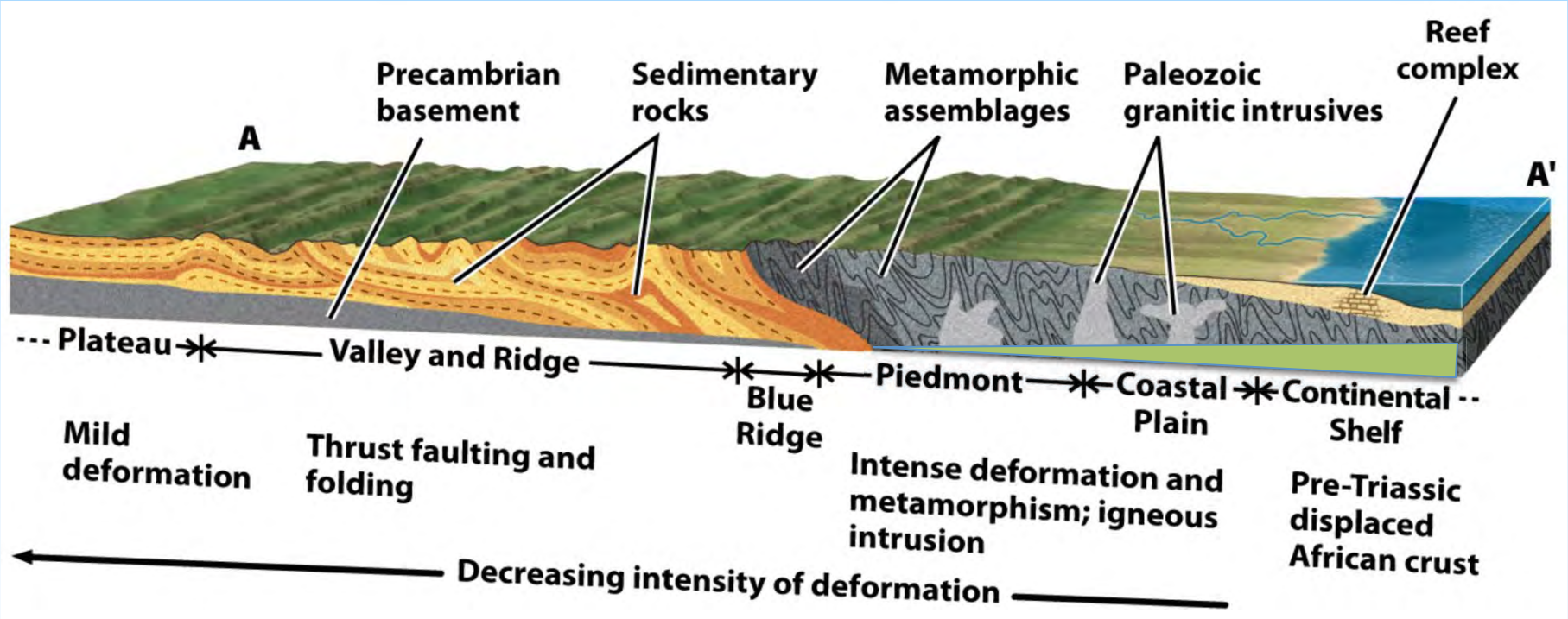


From subduction to collision



Sutures in continents are weak zones that break during the next Wilson cycle.

Example: The Appalachians and the Atlantic margin.



Geodynamic Processes at Rifting and Subducting Margins

Thank you!