



# ATLAS OF EARTH HISTORY

Christopher R. Scotese  
PALEOMAP Project  
University of Texas at Arlington



# Atlas of Earth History

by

Christopher R. Scotese  
PALEOMAP Project  
Department of Geology  
University of Texas at Arlington

© 2001, PALEOMAP Project, ISBN # 0-9700020-0-9

## Introduction

This Paleogeographic Atlas illustrates the plate tectonic development of the ocean basins and continents as well as the changing distribution of land and sea during the past 650 million years. The maps in this atlas are based on the paleogeographic maps of Scotese and Golonka (1992), but have been rendered in an artistic fashion to show the relief of mountain ranges and continental margins, active plate boundaries (blue = sea floor spreading, red=subduction zones), and the extent of climatic belts (green = wet, yellow =dry). The names of the ancient oceans and continents are shown (e.g. Panthalassic Ocean, Laurentia, Cimmeria) along with modern place names (in *italic*). The present-day coastlines, for reference, are overlain in light gray. Accompanying each full-color paleogeographic map is a simplified black & white map showing only the ancient land areas and the present-day coastlines.

The 20 time periods covered in this atlas are: 650 Ma (Late Proterozoic), 514 Ma (Late Cambrian), 458 Ma (Middle Ordovician), 425 Ma (Middle Silurian), 390 Ma (Early Devonian), 356 Ma (Early Carboniferous), 306 Ma (Late Carboniferous), 255 Ma (Late Permian), 237 Ma (Early Triassic), 195 Ma (Early Jurassic), 152 Ma (Late Jurassic), 94 Ma (Late Cretaceous), 69.5 Ma (latest Cretaceous), 50.2 Ma (Middle Eocene), 14.0 (Middle Miocene), 18,000 years ago (Pleistocene), Present-day, and three fanciful maps for 50, 150 and 250 million years in the future. A detailed description of the information used to make each map, the key features of each map, as well as some of the uncertainties associated with each map are described in the section that follows this introduction.

## History of the Atlas

This Paleogeographic Atlas, is just one of a series of atlases, that I have produced since my days as an undergraduate at the University of Illinois (Chicago). The first atlases were published as miniature "flip books" (Scotese, 1975; 1976; and most recently, Scotese, 1997) and computer animations (Scotese and Baker, 1975; Scotese et al., 1981). While a graduate student in Fred Ziegler's lab at the University of Chicago and Rob Van der Voo's paleomagnetic laboratory at the University of Michigan, we published a series of maps, which were a unique combination of plate tectonics, paleomagnetism, and paleogeography (Paleozoic maps, Scotese et al., 1979; Mesozoic and Cenozoic maps, Ziegler et al., 1983). Though other paleogeographic atlases have been published (Smith et al., 1994; Ziegler, 1989), as far as I am aware, these early publications of the Paleogeographic Atlas Project were the first maps to illustrate the plate tectonic and paleogeographic evolution of the ocean basins and continents during the Phanerozoic.

Though based on this early work, the paleogeography has been updated as more recent syntheses have become available for the Jurassic & Cretaceous (Scotese, 1995), Africa (Hulver, 1985), Europe (Ziegler, 1989, 1990), China (Wang, 1985; Nie et al, 1990), Australia (Cook, 1990), SE Asia (Hutchison, 1989), Former Soviet Union (Zonenshain et al., 1990), and globally (Ronov et al., 1984, 1989).

It is important to note that in 1982, Judy Parrish, who was a post-doc at Chicago at the time, added her paleoclimatic interpretations to these early reconstructions (Parrish, 1982; Parrish et al., 1982). Judy's paleoclimatic reconstructions are the basis of the climatic zones shown in this atlas and were the

inspiration for the parametric climate model (PCM) developed by Malcolm Ross and myself (Scotese and Summerhayes, 1986; Scotese and Ross (1996).

In 1984, at the invitation of John Sclater, I joined the research staff at the Institute for Geophysics and started the Paleooceanographic Mapping Project (POMP) - now the PLATES Project. The goal of POMP was to assemble a global, digital compilation of linear magnetic anomaly data and to map the tectonic features of the ocean floor using data from satellite altimetry (Gahagan et al., 1988) in order to construct a comprehensive plate tectonic model describing the development of the ocean basins during the Mesozoic and Cenozoic. This work was carried on in collaboration with Larry Lawver, John Sclater, Dietmar Mueller, Christophe Heubeck, Jean-Yves Royer, David Sandwell, Lisa Gahagan, and Malcolm Ross.

In 1987, Will Sager and I convened a symposium on Mesozoic and Cenozoic plate tectonic reconstructions at Texas A&M University. A symposium volume (Scotese and Sager, 1988) documented, on an ocean-by-ocean basis, the plate tectonic constraints used to reassemble the ocean basins and continents during the Mesozoic and Cenozoic. The Mesozoic and Cenozoic development of the ocean basins shown in this atlas are based on these plate tectonic models (Scotese et al., 1988). The work begun at Texas has also born fruit in the form of the global hotspot models of Mueller et al., 1994, and a digital age of the ocean floor database (Mueller et al., 1996).

Though sea-floor spreading data are sufficient to reconstruct the ocean basins, other information must be used to unlock the Mesozoic and Cenozoic history of the complex convergent belts in China, S. E. Asia, the former Soviet

Union, and the North American Cordillera. The model presented here for China grew largely from informal discussions with David Rowley, Fred Ziegler, Nie Shangyou (Nie et al., 1990; Yin and Nie, 1996) and Celal Sengor (Sengor and Natalin, 1996). The early paleomagnetic syntheses of Lin Jin Lu, were also very useful and thought provoking. The treatment of the terranes of the former Soviet Union is based on the magnificent synthesis of Lev Zonenshain and his colleagues (Zonenshain et al., 1990). The treatment of the exotic terranes of the North American Cordillera is derived largely from the work of Friedman (1983) and Rowley (1992).

The Mesozoic and Cenozoic history of the ocean basins and continents is relatively well understood when compared with our knowledge of the Paleozoic. In the summer of 1988, a symposium on Paleozoic Palaeogeography and Palaeo- biogeography was co-convened with Stuart McKerrow at Oxford. The goal of that symposium was to produce a new set of Paleozoic reconstructions (Scotese and McKerrow, 1990) and test them with available biogeographic, paleomagnetic and paleoclimatic data. The Paleozoic maps shown in this atlas are based on the results of that symposium (McKerrow and Scotese, 1990; Scotese and Barrett, 1990).

It is interesting to note that the oldest paleogeographic reconstruction in this atlas (Vendian Ice Age, 650 Ma) was the last map to be assembled (Scotese et al., 1993; Scotese, 1997). In the early-1990's, as a result of the pioneering work of Moores (1991), Dalziel (1991), and Hoffman (1991), it became clear that the late Proterozoic was a time of supercontinent assembly (Rodinia - 1100 ma), subsequent breakup (approximately 750 Ma), reassembly (Pannotia, 600 Ma), and breakup (550 Ma) (McKerrow et al., 1992). Preliminary paleomagnetic syntheses (Powell et al., 1993;

Meert and Van der Voo, 1994) also suggested that most of the Vendian glacial deposits were deposited at high paleo-latitudes. The Vendian paleogeographic map presented here is based on a model of late Proterozoic plate tectonics developed by myself, Damien Nance (Ohio University) and W.S. McKerrow.

#### The Next Atlas: A Digital Version

Our understanding of the plate tectonic, paleogeographic, and paleoclimatic development of the Earth is an on-going project. Maps such as these, are at best a milestone, a progress report, describing our current state of knowledge and prejudice. In many respects these maps are already out-of-date. New paleomagnetic data summaries are available (Van der Voo, 1993; Bocharova and Scotese, 1993), hot spot models have been refined and debated (Mueller et al., 1994), satellite altimetry data has revealed the ocean floor in unprecedented detail, plate tectonic models have been updated for Asia (Sengor and Natalin, 1996), China (Yin and Nie, 1996), the Arctic & Circum-Pacific (Monger and Nokleberg, 1996), S.E. Asia (Rangin, 1990; Bertrand and Scotese, 1993; Hall and Blundell, 1996), the Former Soviet Union (Zonenshain, et al., 1990; Bocharova, 1993), the regions surrounding Antarctica (Storey et al., 1996), and the early Paleozoic (Dalziel, 1997; MacNiocall et al., 1997; Jurdy et al., 1995; Cocks et al., 1997).

Detailed paleogeographic maps are now available for many parts of the world: Mesozoic and Cenozoic coastlines (Smith et al., 1994), North America (DNAG series; unpublished paleogeographic maps of Cook and Bally, 1975), Tethys (Dercourt et al 1994), Gondwana (Veevers et al., 1996), the Permian (Scotese and Langford, 1995; Ziegler et al. 1996), and the K-T boundary (Upchurch et al., in press).

Paleoclimatic simulations have been run form numerous time periods (Barron et al., 1994; Fawcett et al., 1994; Golonka et al., 1994; Kutzbach and Ziegler, 1994; Otto-Bliesner et al., 1994; Valdes and Sellwood, 1992;), and a global Phanerozoic database of lithologic indicators of climate has been assembled to test the results of the climatic simulations (Boucot et al., 2001).

All of these results, and more, must be incorporated in the next version of the Paleogeographic Atlas. But how?

Though some aspect of the "next atlas" will be published as a series of maps such as these, I envision that the next atlas will be a "digital atlas". GIS technology, especially programs such as ArcView\*, now allows users to view and interact with the geographic data in a dynamic and flexible way. Map information in the form of points, lines and polygons can be queried based on attributes and replotted instantaneously in a variety of map formats and scales.

An Earth System History GIS, (ESH-GIS), has been developed by the PALEOMAP Project. The ESH-GIS runs under ArcView 3.X and is an archive of Phanerozoic and Late Precambrian plate tectonic reconstructions in shapefile format. The ESH-GIS is the foundation upon which the next Paleogeographic Atlas will be built.

#### The Paleogeographic Method

The study of paleogeography has two principle goals. The first goal is to map the past positions of the continents. The second goal is

to illustrate the changing distribution of mountains, lowlands, shallow seas, and deep ocean basins through time.

#### Mapping the Past Positions of the Continents

The past positions of the continents can be determined using the following multiple lines of evidence: paleomagnetism, linear magnetic anomalies, hot spots, paleobiogeography, paleoclimatology, and geologic history.

**Paleomagnetism.** By measuring the remanent magnetic field often preserved in iron-bearing rock formations, paleomagnetic analysis can determine whether a rock was magnetized near the Pole or near the Equator. Paleomagnetism provides direct evidence of a continent's N-S (latitudinal) position, but does not constrain its E-W (longitudinal) position.

**Linear Magnetic Anomalies.** The Earth's magnetic field has another important property. Like the Sun's magnetic field, the Earth's magnetic field "flips" or reverses polarity. Fluctuations, or "anomalies", in the intensity of the magnetic field, occur at the boundaries between normally magnetized sea floor, and sea floor magnetized in the "reverse" direction. The age of these linear magnetic anomalies can be determined using fossil evidence and radiometric age determinations. Because these magnetic anomalies form at the mid-ocean ridges, they tend to be long, linear features (hence the name "linear magnetic anomalies") that are symmetrically disposed about the ridges axes. The past positions of the continents during the last 150 million years can be directly reconstructed by superimposing linear magnetic anomalies of the same age.

**Hot Spot Tracks.** Some of the world's volcanoes are formed by jets of molten rock that probably rise at the boundary between the Earth's core and mantle (about 3000 km deep). These rising plumes, or hot spots, puncture the

lithosphere and as the plates move across the hot spot, a line of islands is generated (like the Hawaiian islands). These hot spot tracks are an accurate record of the motion of the plates during the last 120 million years.

It is unlikely that all hot spots are completely immobile. The best evidence suggests that the Indian Ocean and Atlantic Ocean hot spots do not move very much (only 1% as fast as the plates). The Pacific hot spots, on-the-other-hand, have been slowly drifting northward. The motion of the plates relative to the hot spots can be compared with plate motions predicted by sea floor spreading (see linear magnetic anomalies) and paleomagnetism.

**Paleobiogeography.** The past distribution of plants and animals can give important clues concerning the latitudinal position of the continents as well as their relative positions. Cold-water faunas can often be distinguished from warm-water faunas, and ancient floras both reflect paleo-temperature and paleo-rainfall. The similarity or dissimilarity of faunas and floras on different continents can be used to estimate their geographic proximity. In addition, the evolutionary history of groups of plants and animals on different continents can reveal when these continents were connected or isolated from each other.

**Paleoclimatology.** The Earth's climate is primarily a result of the redistribution of the Sun's energy across the surface of the globe. It is warm near the Equator and cool near the Poles. Wetness, or rainfall, also varies systematically from the equator to the pole. It is wet near the equator, dry in the subtropics, wet in the temperate belts and dry near the poles. Certain kinds of rocks form under specific climatic conditions. For example coals occur where it is wet, bauxite occurs where it is warm and wet, evaporites and calcretes occur where it is warm and dry, and tillites occur where it is wet and cool. The ancient

distribution of these, and other, rock types can tell us how the global climate has changed through time and how the continents have traveled across climatic belts.

Geologic and Tectonic History. In order to reconstruct the past positions of the continents it is necessary to understand the development of the plate tectonic boundaries that separate continents and bring them back together again. Only by understanding the regional geological and tectonic evolution of an area can you determine the location and timing of rifting, subduction, continental collision and other major plate tectonic events.

#### Mapping the Changing Distribution of Mountains, Lowlands, Shallow Seas and Deep Ocean Basins

Some paleogeographic features change very slowly and are easy to map. Other paleogeographic features change very rapidly and, therefore, any map, at best, is an approximation. In this regard, the Earth, since the early Precambrian, has been divided into deep ocean basins (average depth 3.5 km) and high-standing continents (average elevation about 800 meters). Continental lithosphere, because it is less dense, is more buoyant and is not easily subducted, or recycled back into the Earth's interior. As a result, continents are made-up of very old rocks, some dating back 3.8 billion years. The amount of continental lithosphere has probably changed very little during the last 2.6 billion years (possibly increasing 10-15%). What have changed are the shape and the distribution of continents across the globe. The ocean basins, on the other hand, are all less than 150 million years old. Oceanic lithosphere, because it is denser is continually recycled back into the interior of the Earth.

In contrast to the continents and ocean basins, which are permanent geographic features, the height and location of mountain belts and the shape of the Earth's shorelines constantly change. Mountain belts either form where oceanic lithosphere is subducted beneath the margin of a continent, giving rise to a linear range of mountains, like the Andes mountains of western South America, or where continents collide forming, high mountains and broad plateaus like the Himalayan mountains and Tibetan Plateau of central Asia. Less extensive mountains can also form when continents rift apart (e.g. East African Rift), or where hot spots form volcanic uplifts.

In most cases mountain ranges take 10's of millions of years to form, and depending on the climate, may last for 100's of millions of years. Though the Appalachian mountains of the eastern United States were formed over 300 million years ago, due to the collision of North America and western Africa, remnants of this collisional mountain belt still reach heights of over than 2000 meters. The Himalayan Mountains, the world's tallest mountain range, began to rise from the sea nearly 50 million years ago when northern India collided with Eurasia. On the paleogeographic maps shown in this atlas, the extent of the mountain ranges increases during the collisional phase and is slowly reduced, by erosion, in subsequent maps.

In comparison to topographic features such as mountain ranges, the Earth's shorelines are ephemeral. The familiar shapes that characterize today's shorelines such as Hudson's Bay, the Florida peninsula, or the numerous fiords of Norway, are all less than 12,000 years old. The shape of the modern coastlines is the result of a 70 meter rise in sea level that took place in the last 12,000 years after the last

great ice sheet that covered much of North America and Europe had melted.

It is important to note that the shoreline, though the edge of land, is not the edge of the continent. In most cases, the continent extends seaward 100's of kilometers beyond the shoreline. The actual edge of the continent is marked by the transition from the continental slope to the continental rise. This steep bathymetric gradient marks the boundary between continental lithosphere and oceanic lithosphere and is marked by the transition from light blue (shallow shelf) to dark blue (deep ocean).

The position of the shoreline is a function of both continental topography and sea level. Though topography changes slowly (10's of millions of years), global sea level can change rapidly (10's of thousand of years). Several factors can affect sea-level change. As we have seen, one of this factors in the amount of ice on the continents. At times when great ice sheets covered the continents, sea level was low and the continents were exposed. The last glacial maximum was 18,000 years ago. For the last 20 million years, the continents have been largely high and dry because there has been extensive mountain building in Asia and there has been significant ice on Antarctica. Other important global episodes of glaciation occurred 300, 450 and 650 million years ago. The oldest known glacial episode occurred in the Precambrian, approximately 2.2 billion years ago.

Sea level also changes more slowly (10's of millions of years) due to changes in the volume of the ocean basins. Water from the interior of the Earth, erupted as gas in volcanic eruptions, condensed on the cooling surface of the Earth to form the world's oceans. However, there has been no significant addition to the

volume of water on the Earth since early Precambrian times.

Changes in sea level, therefore, are not due to changes in the amount of water on the Earth, but rather are due to changes in the shape and size of the ocean basins.

#### Chronological Review of Maps in this Atlas

The paleogeographic maps shown in this atlas illustrate both the movement of the continents and the changing distribution of mountains, land, shallow sea, and deep sea during the last 650 million years. In the following section is a brief review of the tectonic, geologic, and climatic events portrayed by these maps.

Late Precambrian, 1100 - 545 mya. (Figure 1, Vendian Period, 650 mya).

The absence of fossils of hard-shelled organisms and the paucity of reliable paleomagnetic data make it difficult to produce paleogeographic maps for much of the Precambrian. With available data, 650 million years is about as far back as we can go with any accuracy.

However, the late Precambrian is an especially interesting time because continents were colliding to form ancient supercontinents, and because the Earth was locked in a major Ice Age. About 1100 million years ago, the supercontinent of Rodinia was assembled. Though its exact size and configuration are not known, it appears that North America formed the core of this supercontinent. At that time, the east coast of North America was adjacent to western South America and the west coast of North America lay next to Australia and Antarctica. Rodinia split into two halves approximately 750 million years ago, opening the Panthalassic Ocean (see Figure 2). North America rotated southward



towards the South Pole. The other half of Rodinia, composed primarily of Antarctica, Australia, India, Arabia, and the continental fragments that would one day become China, rotated counter-clockwise, northwards across the North Pole. Between these two halves, lay a third continent, the Congo craton, made up of much of north-central Africa. The oceans between these three continents were completely subducted by the end of the Precambrian and these three continents collided to form a new supercontinent, called Pannotia. This major continent-continent collision is known as the Pan-African orogeny.

As mentioned previously, the climate was cold during the Late Precambrian. Evidence of glaciation is found on nearly every continent. Some researchers have proposed that it was so cold that the Earth was completely frozen like a giant snowball. Why cold conditions were so widespread during the late Precambrian has puzzled geologists. Several hypotheses, now known to be incorrect, have been proposed. One explanation suggests that the Earth was tilted sideways so that the North Pole faced away from the Sun, and the South Pole faced towards the Sun. This would create a situation where 1/2 the Earth would broil under the Sun for 6 months, while the other 1/2 of the Earth would face away from the Sun and completely freeze. Though tantalizing, no mechanism can be found that would produce such a drastic tilt in the Earth's axis. A second, unlikely hypothesis proposes that the Earth was encircled by a rocky and icy ring, much like the rings of Saturn and Uranus that cast a shadow on the Earth, cooling the climate; however, no trace of this ring has been found.

We now know that, though very cold, there was probably nothing unusual going on during the Late Precambrian. These hypotheses were put

forward before accurate paleogeographic maps were available. As Figure 1 illustrates, mystery of the Late Precambrian Ice Age can be explained by the fact that during the late Precambrian many continents just happened to be at high latitudes (except for Australia). Ice rafted debris and glacial deposits formed on these continents as they traveled across the North and South Poles.

Early and Middle Paleozoic, 545 - 360 mya. (Figure 2. Late Cambrian Period, Figure 3. Middle Ordovician, Figure 4. Middle Silurian, Figure 5. Early Devonian) Pannotia, the supercontinent that formed at the end of the Precambrian Era, approximately 600 million years ago, had already begun to break apart by the beginning of the Paleozoic Era. A new ocean, the Iapetus Ocean, widened between the ancient continents of Laurentia (North America), Baltica (Northern Europe), and Siberia. Gondwana, the supercontinent that was assembled during the Pan-African orogeny, was the largest continent at this time, stretching from the Equator to the South Pole. During the Ordovician Period, warm water deposits, such as limestones and salt, are found in the equatorial regions of Gondwana (Australia, India, China, and Antarctica), while glacial deposits and ice-rafted debris occur in the south polar areas of Gondwana (Africa and South America).

By middle Paleozoic time, approximately 400 million years ago, the Iapetus Ocean had closed bringing Laurentia and Baltica crashing together. This continental collision, preceded in many places by the obduction of marginal island arcs, resulted in the formation of the Caledonide mountains in Scandinavia, northern Great Britain and Greenland, and the Northern Appalachian mountains along the eastern seaboard of North America. It is also likely that by middle Paleozoic times, North China and South

China had rifted away from the Indo-Australian margin of Gondwana, and were headed northwards across the Paleo-Tethys Ocean.

Throughout the Early and Middle Paleozoic, the expansive Panthalassic Ocean covered much of the northern hemisphere. Surrounding this ocean was a subduction zone, much like the modern "ring-of-fire" that surrounds the Pacific Ocean.

Late Paleozoic, 360 - 245 mya. (Figure 6. Early Carboniferous, Figure 7. Late Carboniferous, Figure 8. Late Permian). By the end of the Paleozoic Era, most of the oceans that had opened during the breakup of Pannotia were consumed as the continents collided to form the supercontinent of Pangea. Centered on the Equator, Pangea stretched from the South Pole to the North Pole, and separated the Paleo-Tethys Ocean to the east, from the Panthalassic Ocean to the west. During the Late Carboniferous and Early Permian the southern regions of Pangea (southern South America and southern Africa, Antarctica, India, southern India, and Australia) were glaciated. There is evidence of a north polar ice cap in eastern Siberia during the Late Permian. The broad Central Pangean mountain range formed an equatorial highland that during late Carboniferous was the locus of coal production in an equatorial rainy belt. By the mid-Permian, the Central Pangean mountain range had moved northward into drier climates and the interior of North America and Northern Europe became desert-like as the continued uplift of the mountain range blocked moisture-laden equatorial winds.

The term "Pangea" means, "all land". Though we call the supercontinent that formed at the end of the Paleozoic Era, "Pangea", this supercontinent probably did not include all the landmasses that existed at that time. In the eastern hemisphere, on either side of the Paleo-

Tethys Ocean, there were continents that were separated from the supercontinent. These continents were North and South China, and a long "windshield-wiper"-shaped continent known as Cimmeria. Cimmeria consisted of parts of Turkey, Iran, Afghanistan, Tibet, Indochina and Malaya. It appears to have rifted away from the Indo-Australian margin of Gondwana during the Late Carboniferous - Early Permian. Together with the Chinese continents, Cimmeria moved northwards towards Eurasia, ultimately colliding along the southern margin of Siberia during the late Triassic Period. It was only after the collision of these Asian fragments that all the world's landmasses were joined together in a supercontinent deserving of the name "Pangea".

Early Mesozoic, 245 - 144 mya. (Figure 9. Early Triassic, Figure 10. Early Jurassic, Figure 11. Late Jurassic) Pangea was assembled piece-wise. The continental collisions that lead to the formation of the supercontinent began in the Devonian and continued through the Late Triassic. In a similar fashion, the supercontinent of Pangea did not rift apart all at once, but rather was subdivided into smaller continental blocks in three main episodes. The first episode of rifting began in the middle Jurassic, about 180 million years ago. After an episode of igneous activity along the east coast of North America and the northwest coast of Africa, the Central Atlantic Ocean opened as North America moved to the northwest (See Figure 11). This movement also gave rise to the Gulf of Mexico as North America moved away from South America. At the same time, on the other side of Africa, extensive volcanic eruptions along the adjacent margins of east Africa, Antarctica, and Madagascar heralded the formation of the western Indian Ocean.

During the Mesozoic North America and Eurasia were joined together in one landmass, sometimes

called Laurasia. As the Central Atlantic Ocean opened, Laurasia rotated clockwise, sending North America northward, and Eurasia southward. Coals, which were abundant in eastern Asia during the early Jurassic, were replaced by deserts and salt deposits during the Late Jurassic as Asia moved from the wet temperate belt to the dry subtropics. This clockwise, see-saw motion of Laurasia also led to the closure of the wide V-shaped ocean, Tethys, that separated Laurasia from the fragmenting southern supercontinent, Gondwana.

Late Mesozoic, 144 - 66 mya. (Figure 12. Late Cretaceous Period, Figure 13, Cretaceous/Tertiary boundary) The second phase in the breakup of Pangea began in the early Cretaceous, about 140 million years ago. Gondwana continued to fragment as South America separated from Africa opening the South Atlantic, and India together with Madagascar rifted away from Antarctica and the western margin of Australia opening the Eastern Indian Ocean (see Figure 7). The South Atlantic did not open all at once, but rather progressively "unzipped" from south to north. That is why the South Atlantic is wider to the south.

Other important plate tectonic events occurred during the Cretaceous Period. These include: the initiation of rifting between North America and Europe, the counter-clockwise rotation of Iberia from France, the separation of India from Madagascar, the derivation of Cuba and Hispaniola from the Pacific, the uplift of the Rocky mountains, and the arrival of exotic terranes (Wrangellia, Stikinia) along the western margin of North America.

Globally, the climate during the Cretaceous Period, like the Jurassic and Triassic, was much warmer than today. Dinosaurs and palm trees were present north of the Arctic Circle and in

Antarctica and southern Australia. Though there may have been some at the poles during the Early Cretaceous, there were no large ice caps at anytime during the Mesozoic Era.

These mild climatic conditions were in part due to the fact shallow seaways covered the continents during the Cretaceous. Warm water from the equatorial regions was also transported northward, warming the polar regions. These seaways also tended to make local climates milder, much like the modern Mediterranean Sea, which has an ameliorating effect on the climate of Europe.

Shallow seaways covered the continents because sea level was 100 - 200 meters higher than today. Higher sea level was due, in part, to the creation of new rifts in the ocean basins that, as discussed previously in this article, displaced water onto the continents. The Cretaceous was also a time of rapid sea-floor spreading. Because of their broad profile, rapidly spreading mid-ocean ridges displace more water than do slow spreading mid-ocean ridges. Consequently, during times of rapid sea-floor spreading, sea level will tend to rise.

Cenozoic Era, 66 - 0 mya. (Figure 14, Middle Eocene, Figure 15. Middle Miocene) The third, and final phase in the breakup of Pangea took place during the early Cenozoic. North America and Greenland split away from Europe, and Antarctica released Australia, which like India 50 million years earlier, moved rapidly northward on a collision course with Southeast Asia. The most recent rifting events, all taking place within the last 20 million years include: the rifting of Arabia away from Africa opening the Red Sea, the creation of the East African Rift System, the opening of the Sea of Japan as Japan moved eastward into the Pacific, and the northward motion of California and



northern Mexico, opening of the Gulf of California.

Though several new oceans have opened during the Cenozoic, the last 66 million years of Earth history are better characterized as a time of intense continental collision. The most significant of these collisions has been the collision between India and Eurasia, which began about 50 million years ago. During the Late Cretaceous, India approached Eurasia at rates of 15 - 20 cm/yr - a plate tectonic speed record. After colliding with marginal island arcs in the Late Cretaceous, the northern part of India, Greater India, began to be subducted beneath Eurasia raising the Tibetan Plateau. Interesting, Asia, rather than India, has sustained most of the deformation associated with this collision. This is because India is a solid piece of continental lithosphere riding on a plate that is primarily made up of stronger oceanic lithosphere. Asia on the other hand, is a loosely knit collage of continental fragments. The collision zones, or sutures, between these fragments are still warm, and hence, can be easily reactivated. As India collided with Asia, these fragments were squeezed northwards and eastwards out of the way, along strike-slip faults that followed older sutures. Earthquakes along these faults continue to the present-day.

The collision of India with Asia is just one of a series of continental collisions that has all but closed the oceanic Tethys Ocean. From east to west these continent-continent collisions are: Spain with France forming the Pyrenees mountains, Italy with France and Switzerland forming the Alps, Greece and Turkey with the Balkan States forming the Hellenide and Dinaride mountains, Arabia with Iran forming the Zagros mountains, India with Asia, and finally the youngest collision, Australia with Indonesia.

This phase of continental collision has raised high mountains by horizontally compressing the continental lithosphere. Though the continents occupy the same volume, their area has decreased slightly. Consequently, on a global scale, the area of the ocean basins has increased slightly during the Cenozoic, at the expense of the continents. Because the ocean basins are larger, they can hold more water. As a result, sea level has fallen during the last 66 million years. In general, sea level is lower during times of continental collision (early Devonian, Late Carboniferous, Permian, Triassic).

During times of low sea level the continents are emergent, land faunas flourish, migration routes between continents open up, the climate becomes more seasonal, and probably most importantly, the global climate tends to cool off. This is largely because land tends to reflect the Sun's energy back to space, while the oceans absorb the Sun's energy. Also, landmasses permit the growth of permanent ice sheets, which because they are white reflect even more energy back to space. The formation of ice on the continents, of course, lowers sea level even further, which results in more land, which cools the Earth, forming more ice, and so on, and so on. The lesson here is: once the Earth begins to cool (or warm-up) positive feedback mechanisms push the Earth's climate system to greater and greater cooling (or heating). During the last half of the Cenozoic the Earth began to cool off. Ice sheets formed first on Antarctica and then spread to the northern hemisphere. For the last 5 million years the Earth has been in a major Ice Age. There have been only a few times in Earth's history when it has been as cold as it has been during the last 5 million years.

Modern World. (Figure 16. Last Glacial Maximum, Figure 17. Present-day) 18,000 years ago,

glaciers and great sheets of ice covered all of Antarctica, and much of North America, northern Europe, and the mountainous regions of the world. These ice sheets melted approximately 10,000 years ago giving rise to such familiar geographic features as Hudson's Bay, the Great Lakes, the English Channel, and the fiords of Norway.

The continental rifting and collisions that began in the late Cenozoic are continuing today. Most notable are: the opening of the Red Sea and Gulf of Aden, the rifting of East Africa, the opening of the Gulf of California and the northward translation of California west of the San Andreas Fault, and the incipient collision of Australia with Indonesia giving rise to the mountain ranges of New Guinea.

Future World , 0 - 250 myf. (Figure 18 100 million years in future; Figure 19, 150 million years in future; Figure 20, 250 million years in future). Though there is no way of knowing what the future geography of the Earth will be, it is possible to project current plate motions into the future and make an educated guess. The three maps presented here show the Earth at 100 million, 150 million and 250 million years in the future. In general the Atlantic and Indian oceans continue to widen until new subduction zones recycle the ocean floor in these ocean basins and bring the continents back together in a new Pangean configuration some 250 million years in the future.

The reconstruction of the world 50 million years in the future looks slightly askew (Figure 18). On this map, North America is rotated counter-clockwise, while Eurasia is rotated clockwise bringing England closer to the North Pole and Siberia down to warm subtropical latitudes. Africa has collided with Europe and Arabia closing the Mediterranean Sea and the Red Sea.

Similarly, Australia has beached itself on the doorstep of Southeast Asia and a new subduction zone encircles Australia and extends westward across the Central Indian Ocean. It is interesting to note that plate trajectories suggest that the East African Rift will not grow into a wide ocean.

Though the Atlantic Ocean has widened, extensions of the Puerto Rican Trough and the Scotia Arc have started a new subduction zone along the eastern edge of the Americas. In time, this subduction zone will consume the North and South Atlantic oceans.

The map of the world at 150 million years in the future shows the contraction of the Atlantic and Indian Oceans. Antarctica has collided with Australia, and the Mid-Atlantic Ridge has nearly been subducted beneath the Eastern American subduction zone (Figure 19).

In the final reconstruction of future plate motions (Figure 20), the Indo-Atlantic Ocean is completely closed. North America has collided back against Africa, but in a more southerly position that juxtaposes Miami with Cape Town. South America wraps around the southern tip of Africa, with Patagonia in contact with Indonesia enclosing a remnant of the Indian Ocean. Antarctica is once again at the South Pole, and a Pacific has grown wider, encircling half the Earth.

#### Acknowledgements

Special thanks to Ralph Scotese, who painted the maps, and to James R. Marlatt, Alan Smith, Shawn Stephens, and William Reilly, who helped to produce the computer graphic overlays.

For additional information: email -  
chris@scotese.com, FAX - 817 261 6293, or  
phone, 817 275 1697.

\*ArcView is a registered trademark of ESRI

#### References Cited

Barron, E.J., Fawcett, P.J., Pollard, D., and Thompson, S., 1994. Model simulations of Cretaceous climates: the role of geography and carbon dioxide, in J.R.L. Allen, B.J. Hoskins, B.W. Sellwood, R.A. Spicer, and P.J. Valdes (eds.), *Palaeoclimates and their Modelling: with special reference to the Mesozoic era*, Chapman & Hall, London, pp. 99-107.

Bertrande, G., and Scotese, C.R., 1993. Plate Tectonic Reconstructions of Southeast Asia (0-40 ma). PALEOMAP Project Progress Report 55, pp.

Bocharova, N. Yu., 1993. Plate Tectonic Evolution of the CIS (former Soviet Union), PALEOMAP Project Report 57-1293, 28 pp.

Bocharova N. Yu., and Scotese, C.R., 1993. Revised Global Apparent Polar Wander Paths and Global Mean Poles, PALEOMAP Project Progress Report 56-1293, 20 pp.

Boucot, A.J., Xu, C., and Scotese, C.R., 2001. Atlas of Lithological Indicators of Climate, Geol. Soc. Amer. Special Paper.

Cocks, L.R.M., McKerrow, W.S., and van Staal, C.R., 1997. The margins of Avalonia, Geol. Mag., 134 (5), 627-634.

Cook, P.J., 1990. Australia: Evolution of a Continent, BMR Palaeogeographic Group, Australian Government Publishing Service, Canberra, 97 pp.

Cook, T.D., and Bally, A.W., 1975. Stratigraphic Atlas of North and Central America, Princeton University Press, 272 pp.

Dalziel, I.W. D., 1991. Pacific margins of Laurentia and East Antarctica-Australia as a conjugate rift pair: Evidence and implications for an Eocambrian supercontinent, *Geology*, 19: 598-601.

Dalziel, I.W.D., 1997. Neoproterozoic-Paleozoic geography and tectonics: review, hypothesis and environmental speculation, *Geol. Soc. Amer. bull.*, 109:16-42.

Dercourt, J., Ricou, L.E., and Vrielynck, B., (eds.), 1993. Atlas Tethys Palaeoenvironmental Maps. Gauthier-Villars, Paris, 307 p., 14 maps, 1 pl.

Fawcett, P. J., Barron, E.J., Robinson, V.D., and Katz, B.J., 1994. The climatic evolution of India and Australia from the Late Permian to mid-Jurassic: a comparison of climate model results with the geologic record, in G.D. Klein (ed.), *Pangea: Paleoclimate, Tectonics, and Sedimentation during Accretion, Zenith, and Breakup of a Supercontinent*, Geol. Soc. America Special Paper 288, 139-157.

Friedman, R. M., 1983. Accretionary History of Western North America during the Mesozoic and Cenozoic Eras, Master Thesis, University of Chicago, 512 pp.

Gahagan, L.M., Scotese, C.R., Royer, J.-Y., Sandwell, D.T., Winn, J.K., Tomlins, R. L., Ross, M.I., Newman, J.S., Mueller, R.D., Mayes, C.L., Lawver, L.A., and Heubeck, C.E., 1988. Tectonic fabric of the ocean basins from satellite altimetry data, in C.R. Scotese and W.



- W. Sager (eds.), Mesozoic and Cenozoic plate reconstructions, *Tectonophysics*, 155: 1-26.
- Golonka, J., Ross, M.I., and Scotese, C.R., 1994. Phanerozoic paleogeographic and paleoclimatic modeling maps, in A.F. Embry, B. Beauchamp, and D.J. Glass (eds.), *PANGAEA: Global Environments and Resources*, Can. Soc. Petrol. Geol., Memoir 17, pp. 1-48.
- Hall, R., and Blundell, D.J., 1996. Tectonic Evolution of Southeast Asia, *Geological Soc. of London, Special Publ. No. 106*, London, pp. 566.
- Hoffman, P.F., 1991. Did the breakout of Laurentia turn Gondwanaland inside out?, *Science*, 252:1409-1412.
- Hulver, M., 1985. Cretaceous Marine Paleogeography of Africa, Master's Thesis, University of Chicago.
- Hutchison, C. S., 1989. *Geological Evolution of South-east Asia*, Oxford University Press, Oxford, 368 pp.
- Jurdy, D.M., Stefanick, M., and Scotese, C.R., 1995. Paleozoic plate dynamics, *J. Geophys. Res.*, 100: 17965-17975.
- Kutzbach, J.E., and Ziegler, A.M., 1994. Simulation of Late Permian climate and biomes with an atmosphere-ocean model: comparisons and observations, in J.R.L. Allen, B.J. Hoskins, B.W. Sellwood, R.A. Spicer, and P.J. Valdes (eds.), *Palaeoclimates and their Modelling: with special reference to the Mesozoic era*, Chapman & Hall, London, pp. 119-132.
- MacNiocall, C., van der Pluijm, and van der Voo, R., 1997. Ordovician paleogeography and the evolution of the Iapetus Ocean, *Geology* 25: 159-162.
- McKerrow, W.S, and Scotese, C.R., 1990. *Palaeozoic Biogeography and Paleogeography*, Geological Society of London, Memoir 12, 435 pp.
- McKerrow, W.S., Scotese, C.R., and Brasier, M.F., 1992. Early Cambrian continental reconstructions, *J. Geol. Soc.*, London, 149: 599-606.
- Meert, J.G., and Van der Voo, R., 1994. The Neoproterozoic (1000 - 540 Ma) glacial intervals: No more snowball earth?, *Earth Planet. Sci. Letters*, 123: 1-13.
- Monger, J.W.H., and Nokleberg, W.J., 1996. Evolution of the northern North American Cordillera: generation, fragmentation, displacement and accretion of successive North American plate-margin arcs, in Coyner, A.R., and Fahey, P.L., eds., *Geology and Ore Deposits of the American Cordillera*, *Geol. Soc. Nevada Sympos. Proceedings*, Reno/Sparks, Nevada, April 1995, p. 1133-1152.
- Moores, E.M., 1991. Southwest U.S. - East Antarctica (SWEAT) connection: A hypothesis, *Geology*, 19: 425-428.
- Mueller, R.D., Roest, W.R., Royer, J.-Y., Gahagan, L.M., and Sclater, J.G., 1996. Age of the Ocean Floor, Report MGG-12, Data Announcement 96-MGG-04, National Geophy. Data Center, Boulder, Co.
- Mueller, R.D., Royer, J.-Y., Lawver, L.A., 1994. Revised plate motions relative to hot spots from combined Atlantic and Indian Ocean hotspot tracks, *Geology*. X
- Nie, S., Rowley, D.B., and Ziegler, A.M., 1990. Constraints on the location of the Asian microcontinents in the Palaeo-Tethys during the

Late Palaeozoic, In: W.S. McKerrow and C. R. Scotese, eds., Palaeozoic Biogeography and Palaeogeography, Geological Society of London, Memoir 12, pp. 397-410.

Otto-Bliesner, B.L., Becker, E., Becker, N., 1994. Atlas of Phanerozoic Paleoclimate Simulated by a Global Climate Model, Center for Earth System History, Report #1, November 1994, University of Texas at Arlington, 148 pp.

Parrish, J.T., 1982. Upwelling and petroleum source beds, with reference to the Paleozoic. Amer. Assoc. Petro. Geol., 66: 750-774.

Parrish, J.T., Ziegler, A.M., and Scotese, C.R., 1982. Rainfall patterns and the distribution of coals and evaporites in the Mesozoic and Cenozoic, Palaeogeog., Palaeoclim., Palaeoecol., 40: 67-101.

Powell, C.McA., Li, Z.X., McElhinny, M.W., Meert, J.G., and Park, J.K., 1993. Paleomagnetic constraints on the timing of the Neoproterozoic breakup of Rodinia and the Cambrian formation of Gondwana, Geology, 21: 889-892.

Rangin, C., Jolivet, L., Pubellier, M., and the Tethys Pacific working group, 1990. A simple model for the tectonic evolution of southeast Asia and Indonesia region for the past 43 m.y., Bull. Soc. geol. France, (8), t.VI, N.X, pp. 889-905.

Ronov, A., Khain, V., and Seslavinsky, K., 1984. Atlas of Lithological-Paleogeographical Maps of the World, Late Precambrian and Paleozoic of Continents, U.S.S.R. Academy of Sciences, Leningrad, 70 pp.

Ronov, A., Khain, V., and Balukhovsky, 1989. Atlas of Lithological-Paleogeographical Maps of the World, Mesozoic and Cenozoic of Continents

and Oceans, U.S.S.R. Academy of Sciences, Leningrad, 79 pp.

Rowley, D.B., 1992. Reconstructions of the Circum-Pacific Region, in G.E.G. Westermann (editor), The Jurassic of the Circum-Pacific, Cambridge University Press, pp. 15-18.

Scotese, C.R., 1975. Continental Drift, 1st edition, Department of Geology, University of Illinois, Chicago.

Scotese, C.R., 1976. A continental drift "flip book", Computers and Geology, 2:113-116.

Scotese, C.R., 1997. Continental Drift, 7th edition, PALEOMAP Project, Arlington, Texas, 79 pp.

Scotese, C.R., and Baker, D.W., 1975. Continental drift reconstructions and animations, J. Geol. Education, 23:167-171.

Scotese, C.R., and Barrett, S.F., 1990. Gondwana's movement over the South pole during the Palaeozoic: evidence from lithological indicators of climate, in W.S. McKerrow and C. R. Scotese, eds., Palaeozoic Biogeography and Palaeogeography, Geological Society of London, Memoir 12, pp. 75-86.

Scotese, C.R., and Golonka, J. 1992. Paleogeographic Atlas, PALEOMAP Progress Report 20-0692, Department of Geology, University of Texas at Arlington, 34 pp.

Scotese, C.R., and Langford, R. P., 1995. Pangea and the Paleogeography of the Permian, in P.A. Scholle, T.M. Peryt, and D.S. Ulmer-Scholle, eds., The Permian of Northern Pangea, volume 1, Paleogeography, Paleoclimates, and Stratigraphy, Springer-Verlag, Berlin, p. 3-19.

Scotese, C.R., and Ross, M.I., 1996, An Atlas of Paleoclimate Simulations using the Parametric Climate Model (PCM).

Scotese, C.R., and Sager, W.W., 1988. Mesozoic and Cenozoic Plate Tectonic Reconstructions. *Tectonophysics*, 155: 27-48.

Scotese, C.R., and Summerhayes, 1986. A computer model of paleoclimate to predict upwelling in the Mesozoic and Cenozoic. *Geobyte*, 1:28-42.

Scotese, C.R., Gahagan, L.M., and Larson, R. L., 1988. Plate tectonic reconstructions of the Cretaceous and Cenozoic ocean basins, in C.R. Scotese and W. W. Sager (eds.), *Mesozoic and Cenozoic plate reconstructions*, *Tectonophysics*, 155: 27-48.

Scotese, C.R., Snelson, S., Ross, W.C., and Dodge, L., 1981. A computer animation of continental drift, *J. Geomag. Geoelectr.*, 32: suppl. III, 61-70.

Scotese, C.R., Bambach, R.K., Barton, C., Van der Voo, R., and Ziegler, A.M., 1979. Paleozoic Base Maps, *J. Geology*, 87: 217-277.

Sengor, A. M. C., 1996. Paleotectonics of Asia: fragments of a synthesis, in An Yin and Mark Harrison (eds.), *The Tectonic Evolution of Asia*, pp. 486-641.

Smith, A.G., Smith, D.G., and Funnell, B.M., 1994. *Atlas of Mesozoic and Cenozoic Coastlines*, Cambridge University Press, Cambridge, 99 pp.

Storey, B.C., King, E.C., and Livermore, R.A., 1996. Weddell Sea Tectonics and Gondwana Break-up, *Geol. Soc. London Special Publ. No. 108*, London, 284 pp.

Valdes, P. J., and Sellwood, B.W., 1992. A paleoclimate model for the Kimmeridgian, *Palaeo geog., Palaeoclim., Palaeoecol.*, 95: 47-72.

Van der Voo, R., 1993. *Paleomagnetism of the Atlantic, Tethys, and Iapetus Oceans*, Cambridge University Press, Cambridge, 411 pp.

Wang, H., 1985. *Atlas of the Paleogeography of China*, Institute of Geology, Chinese Academy of Sciences, Wuhan College of Geology, Cartographic Publishing House, Beijing, 143 pp.

Yin, A., and Nie, Shangyou, 1996. A Phanerozoic palinspastic reconstruction of China and its neighboring regions, in An Yin and Mark Harrison (eds.), *The Tectonic Evolution of Asia*, pp. 442-486.

Ziegler, A.M., Scotese, C.R., and Barrett, S.F., 1983. Mesozoic and Cenozoic paleogeographic maps, in *Tidal Friction and the Earth's Rotation II*, P. Broche / J. Sundermann, Eds., Springer-Verlag, Berlin.

Ziegler, A.M., Hulver, M.L., and Rowley, D.B., 1996. Permian World Topography and Climate, in I.P. Martini (ed.), *Late Glacial and Postglacial Environmental Changes - Quaternary, Carboniferous-Permian and Proterozoic*, Oxford Univ. Press, New York.

Ziegler, P.A., 1989. *Evolution of Laurussia: a study in late Paleozoic plate tectonics*, Kluwer Academic Publishers, London, 102 pp.

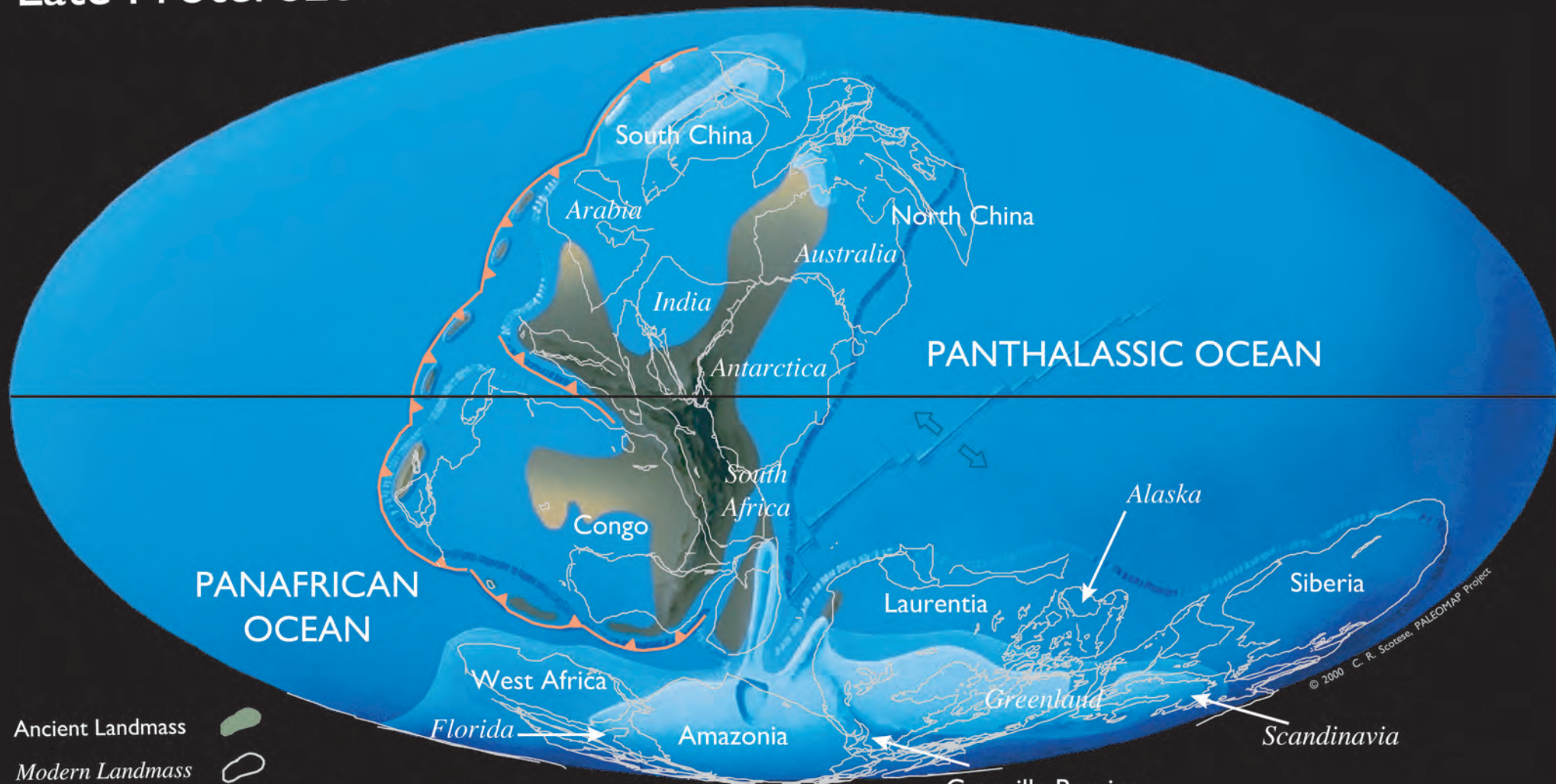
Ziegler, P.A., 1990. *Geological Atlas of Western and Central Europe*, 2nd and completely revised edition, Shell International Petro. Maatschappi B.V., Geological Society Publishing House, Bath, 239 pp., 56 enclosures.



Zonenshain, L., Kuzmin, M.I., and Natapov, L.M.,  
1990. Geology of the U.S.S.R.: A Plate Tectonic  
Synthesis. American Geophysical Union,  
Geodynamics Series, 21: 1-242.x

This atlas should be referenced as:  
Scotese, C.R., 2001, Atlas of Earth History,  
Volume 1, Paleogeography, PALEOMAP Project,  
Arlington, Texas, 52 pp.

# Late Proterozoic 650 Ma



Ancient Landmass

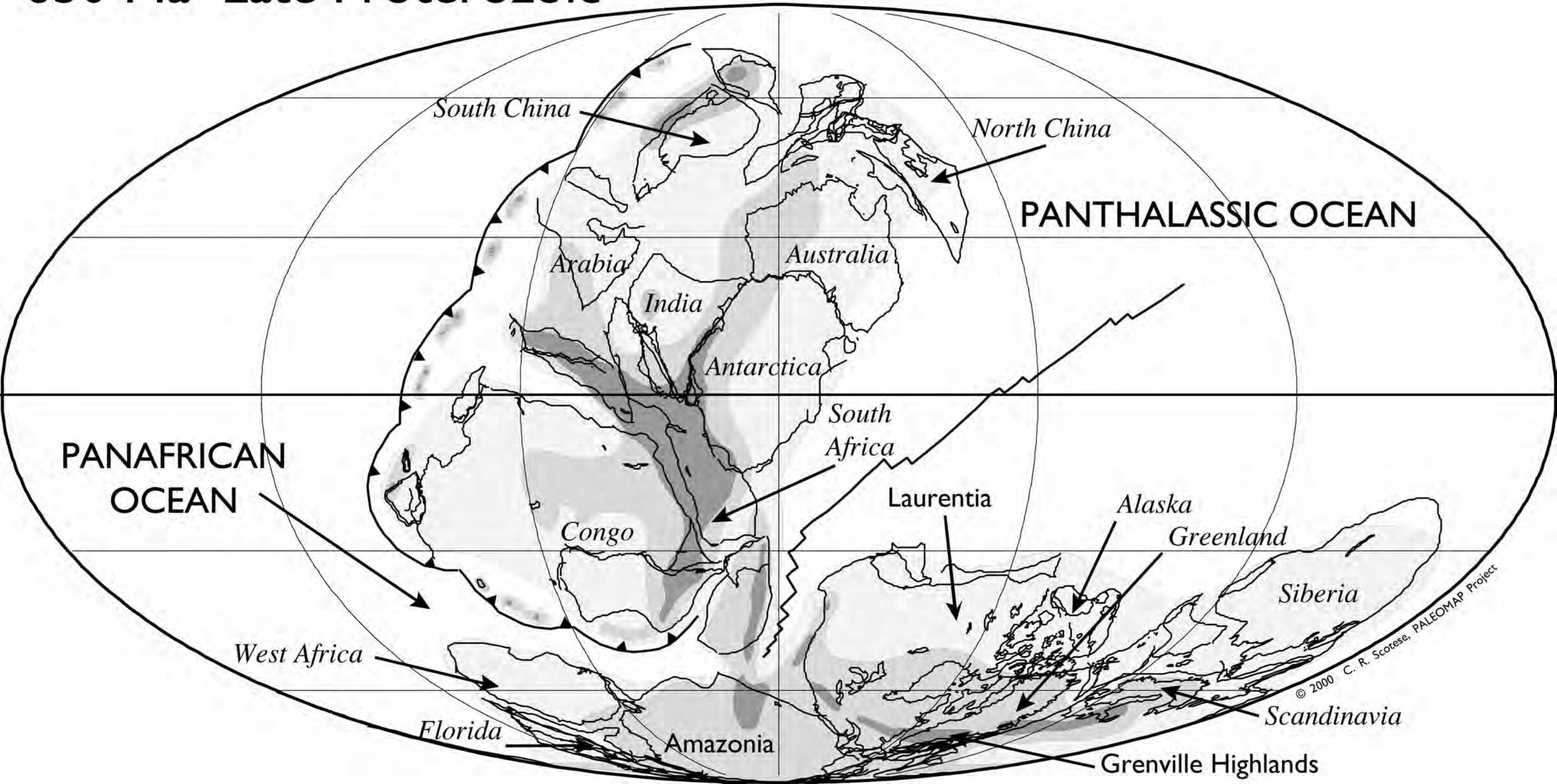
Modern Landmass

Subduction Zone (triangles point in the direction of subduction)

Sea Floor Spreading Ridge

© 2000 C. R. Scotese, PALEOMAP Project

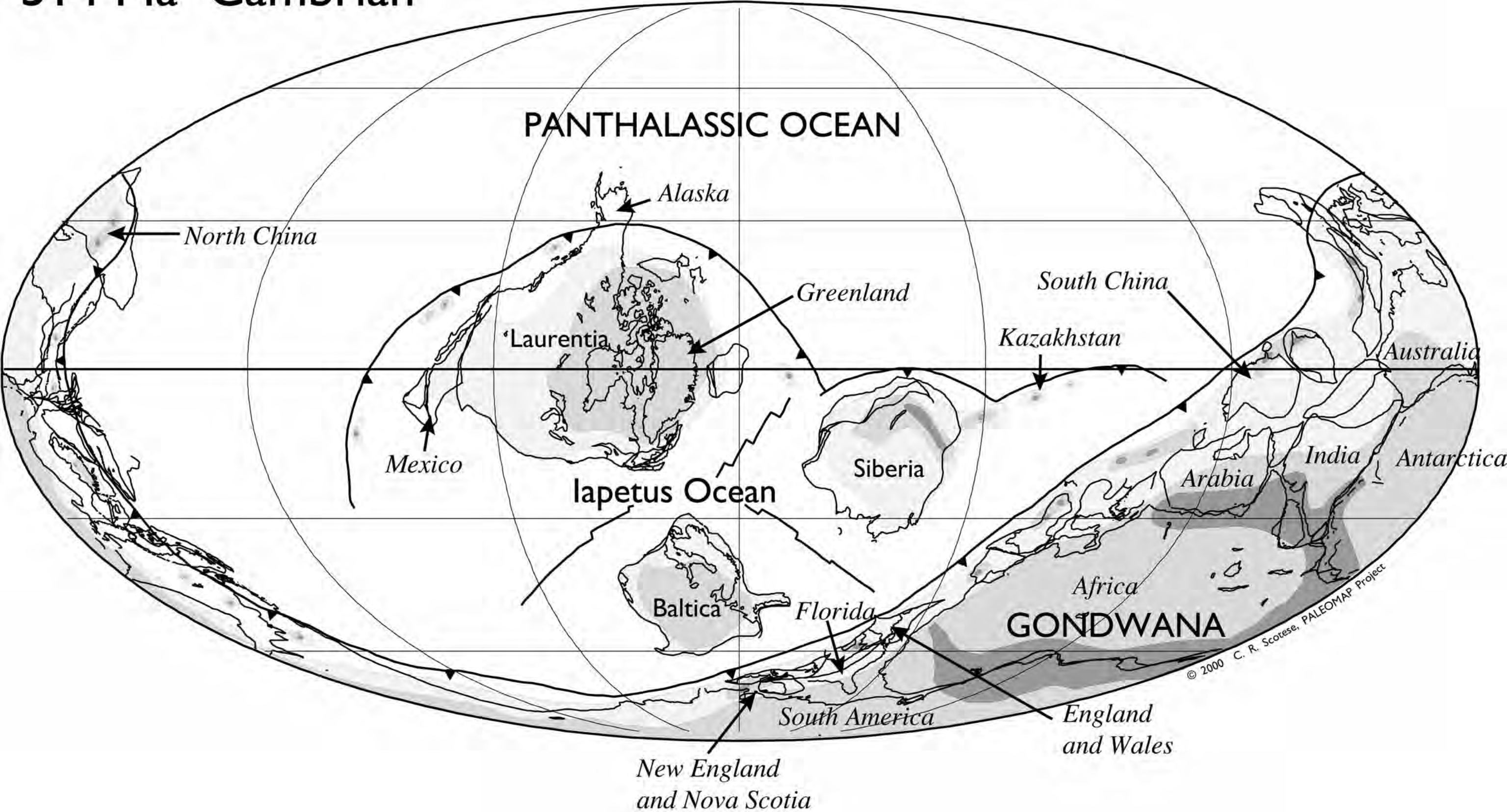
# 650 Ma Late Proterozoic





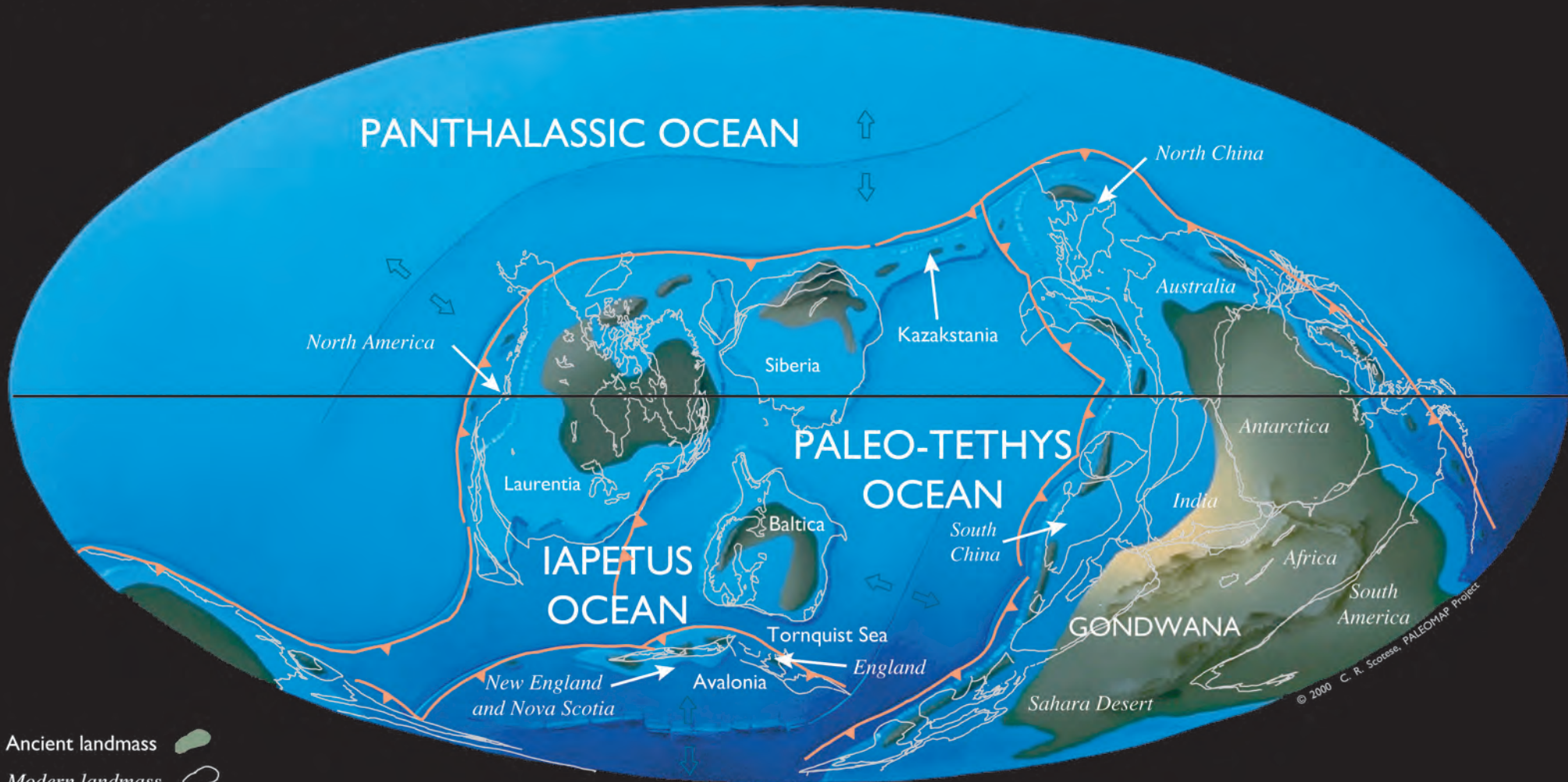


# 514 Ma Cambrian





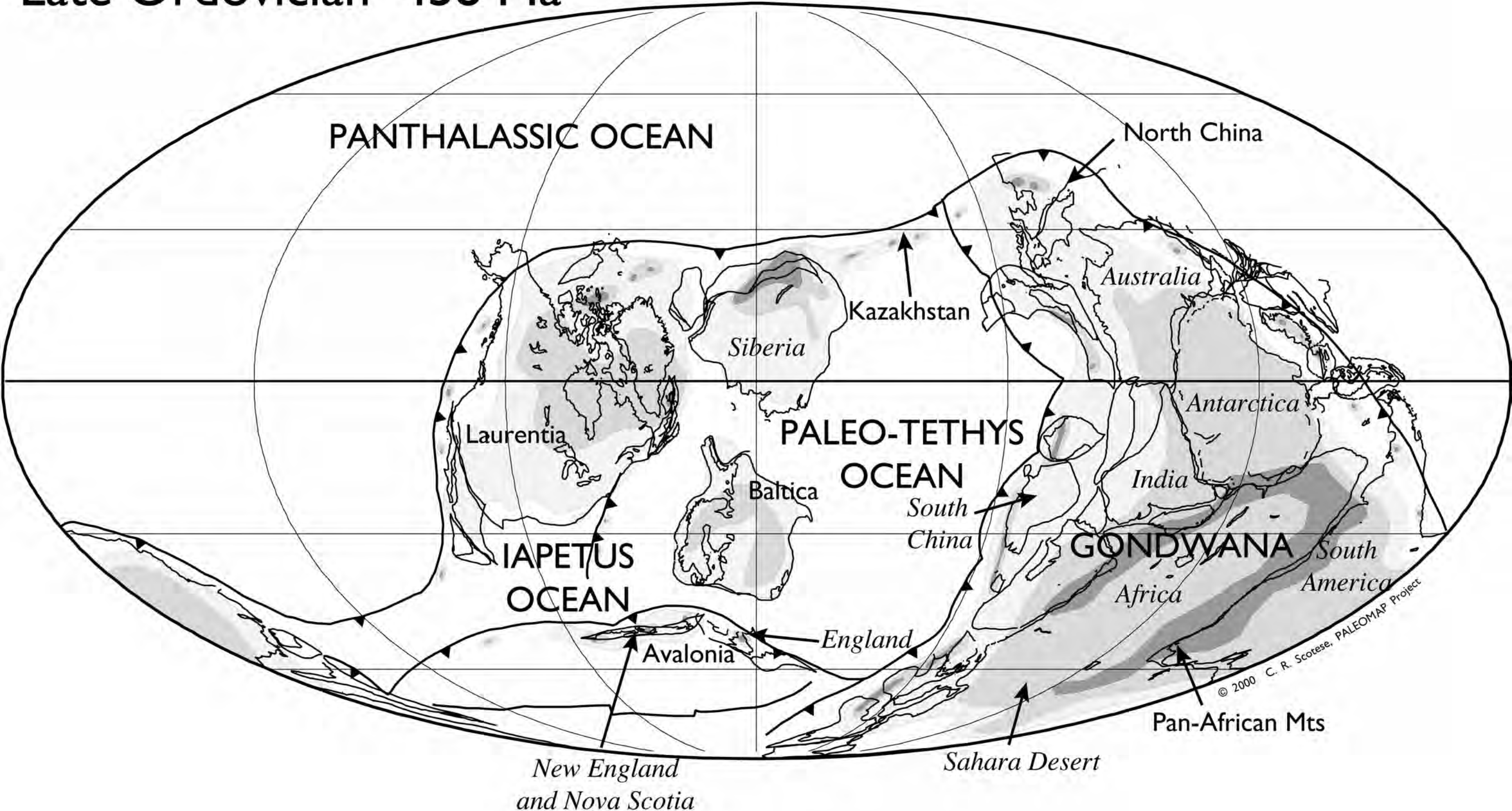
# Middle Ordovician 458 Ma



- Ancient landmass
- Modern landmass
- Subduction Zone (triangles point in the direction of subduction)
- Sea Floor Spreading Ridge

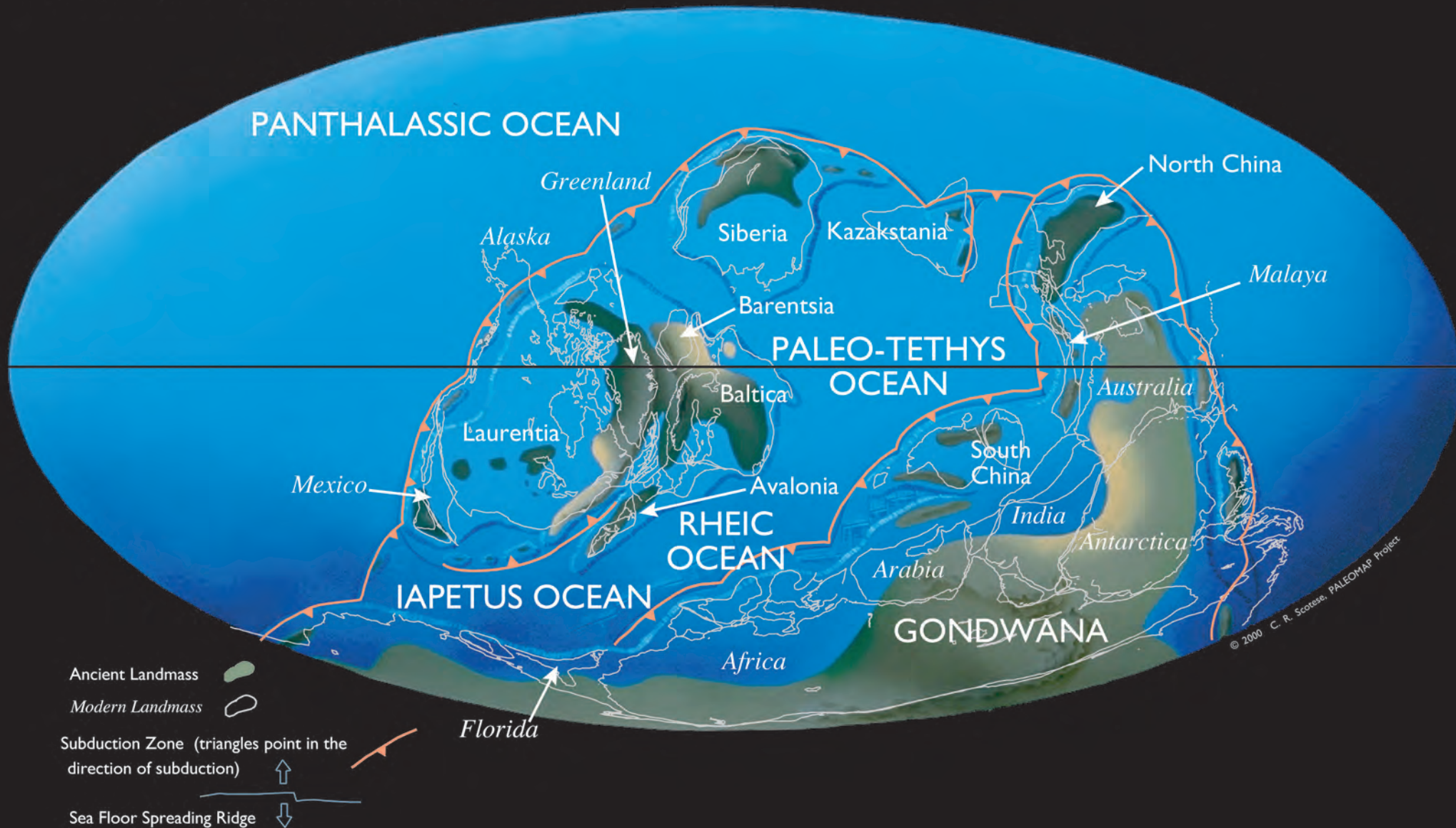
© 2000 C. R. Scotese, PALEOMAP Project

# Late Ordovician 458 Ma

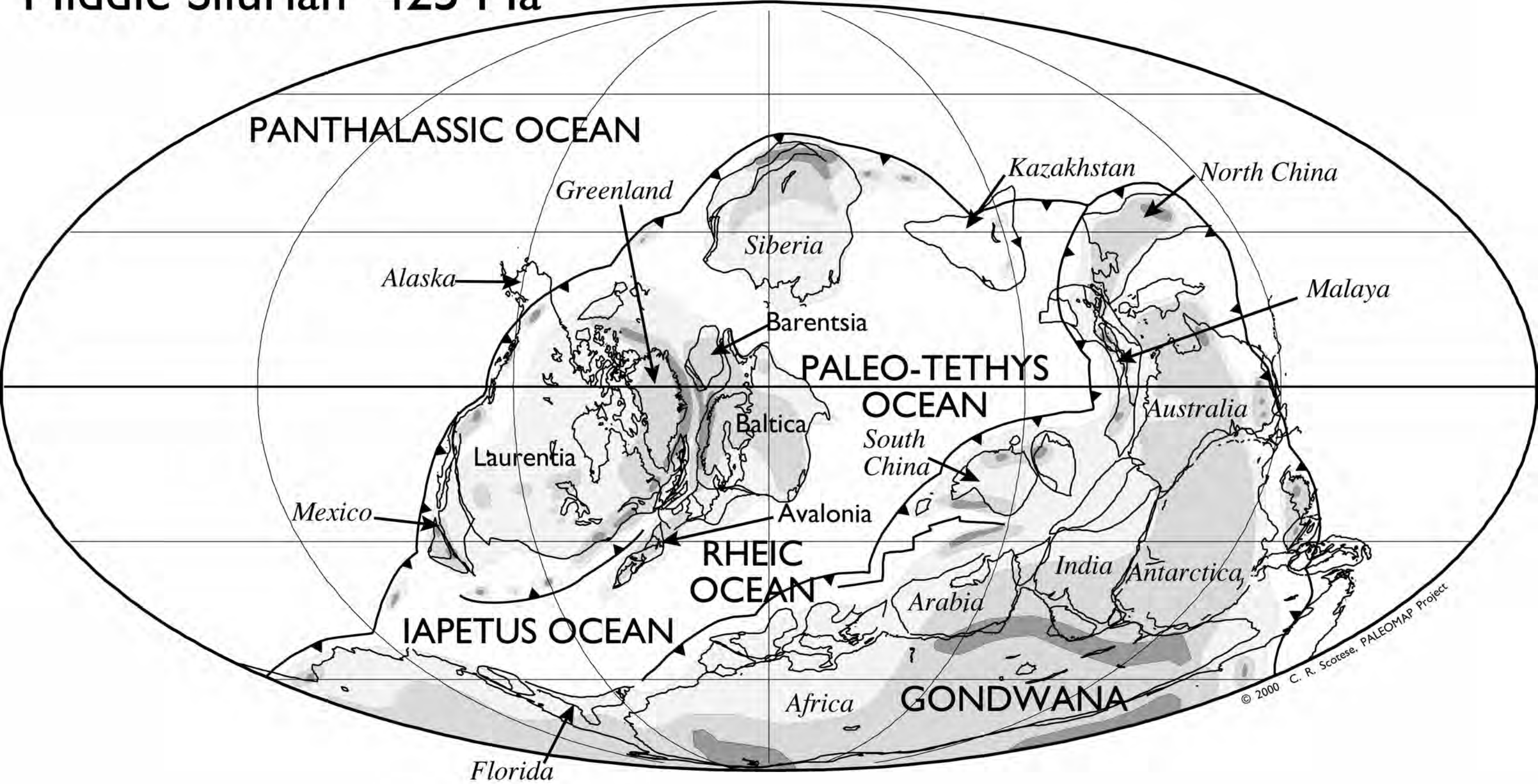




# Middle Silurian 425 Ma







# Middle Silurian 425 Ma





# Early Devonian 390 Ma



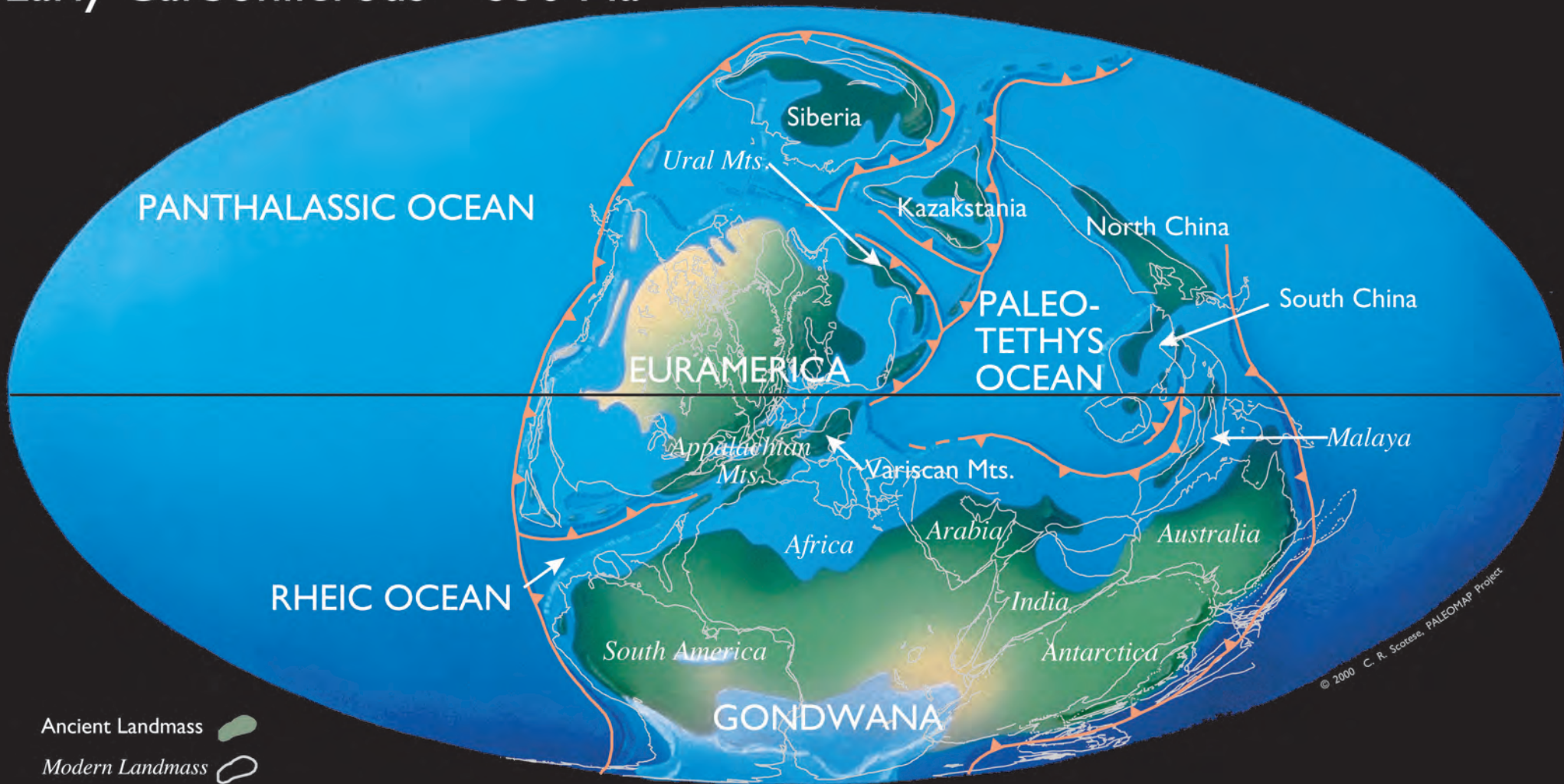
- Ancient Landmass 
- Modern Landmass 
- Subduction Zone (triangles point in the direction of subduction) 
- Sea Floor Spreading Ridge 






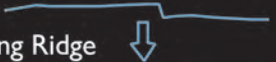
# Early Devonian 390 Ma



# Early Carboniferous 356 Ma

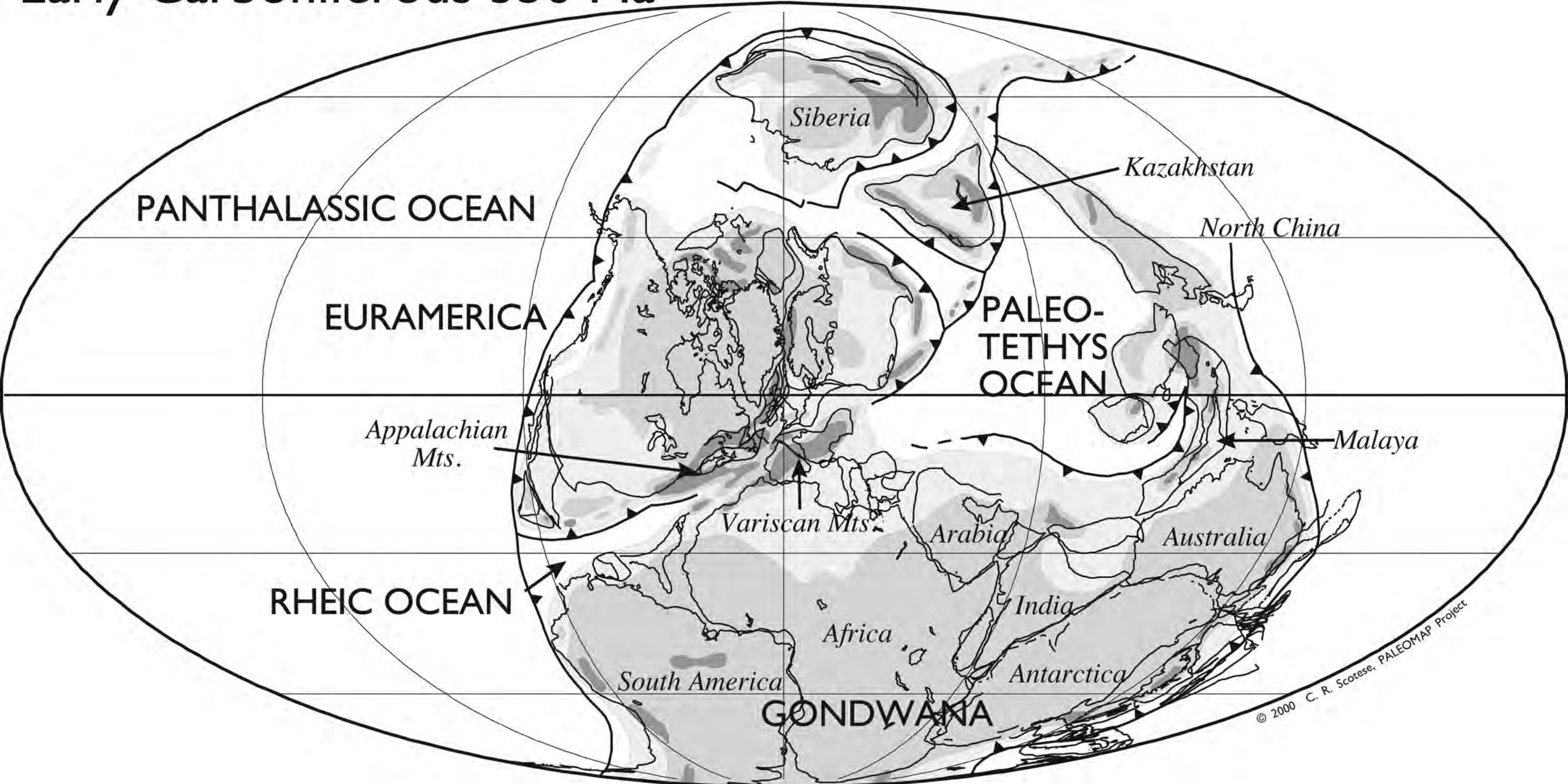


Ancient Landmass   
Modern Landmass 

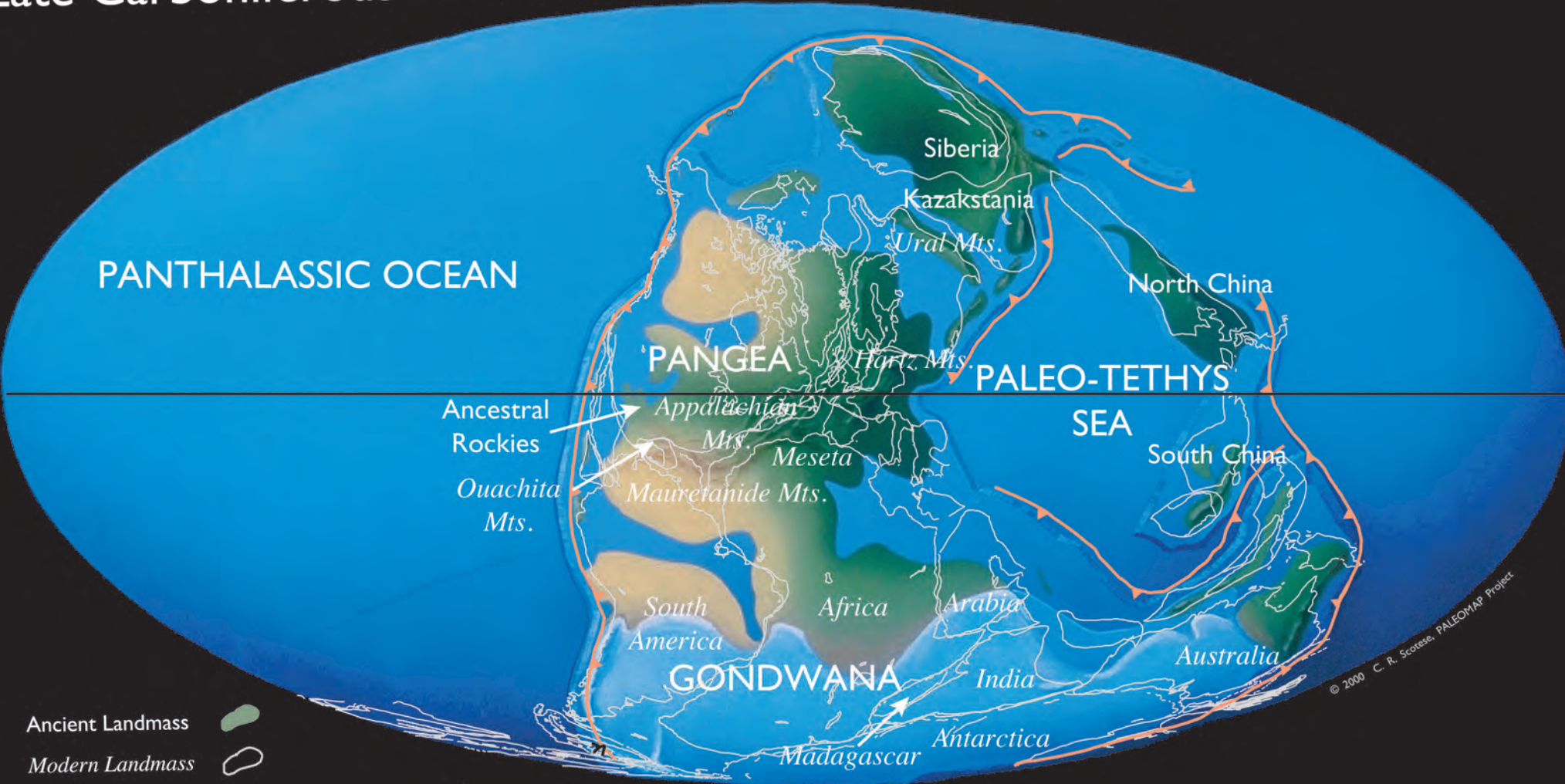
Subduction Zone (triangles point in the direction of subduction)    
Sea Floor Spreading Ridge 



# Early Carboniferous 356 Ma



# Late Carboniferous 306 Ma



PANTHALASSIC OCEAN

PANGEA

PALEO-TETHYS

SEA

GONDWANA

Ancient Landmass



Modern Landmass



Subduction Zone (triangles point in the direction of subduction)



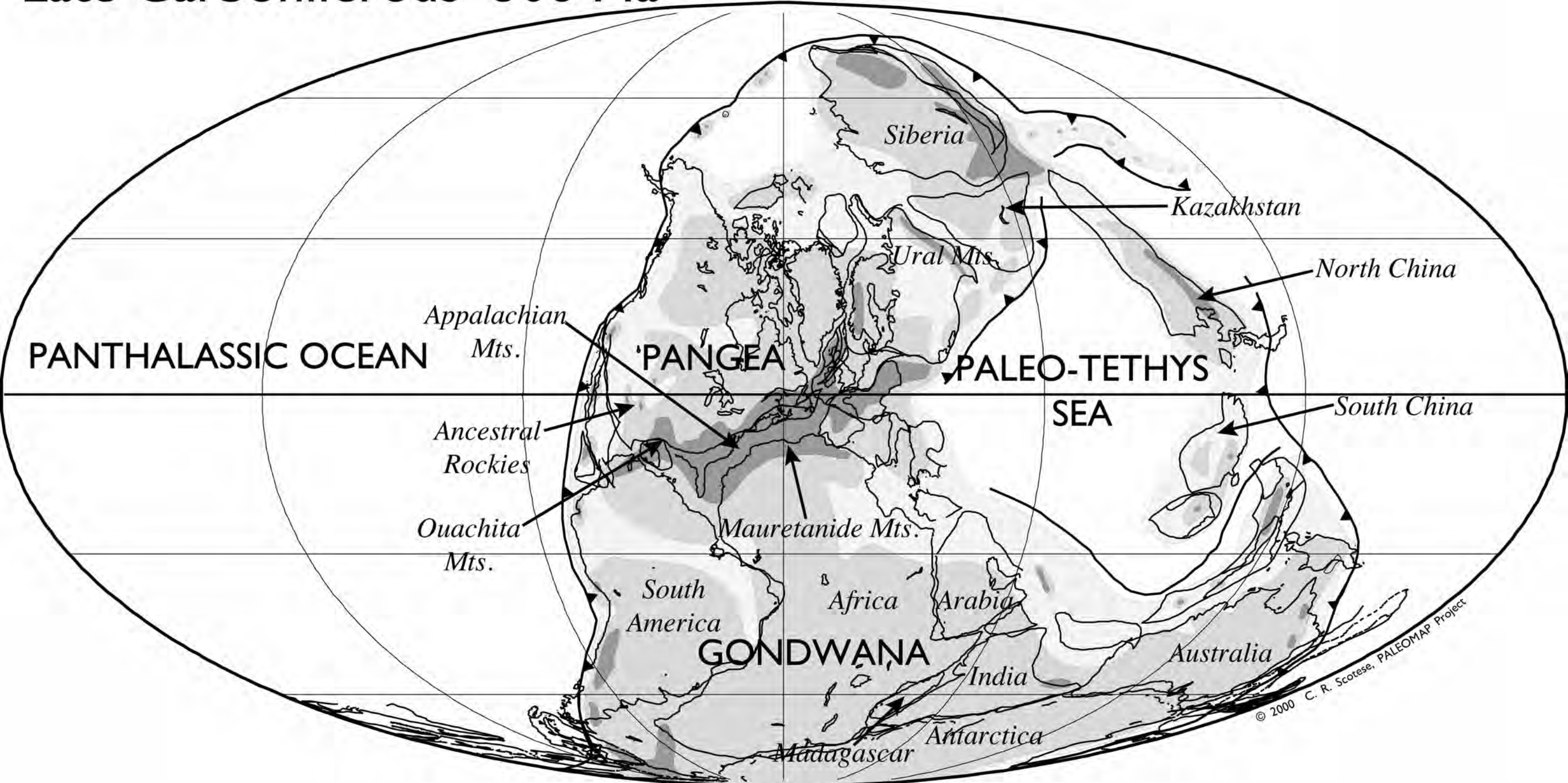
Sea Floor Spreading Ridge



© 2000 C. R. Scotese, PALEOMAP Project



# Late Carboniferous 306 Ma





Late Permian 255 Ma



PANGEA

PANTHALASSIC OCEAN

PALEO-TETHYS OCEAN

GONDWANA

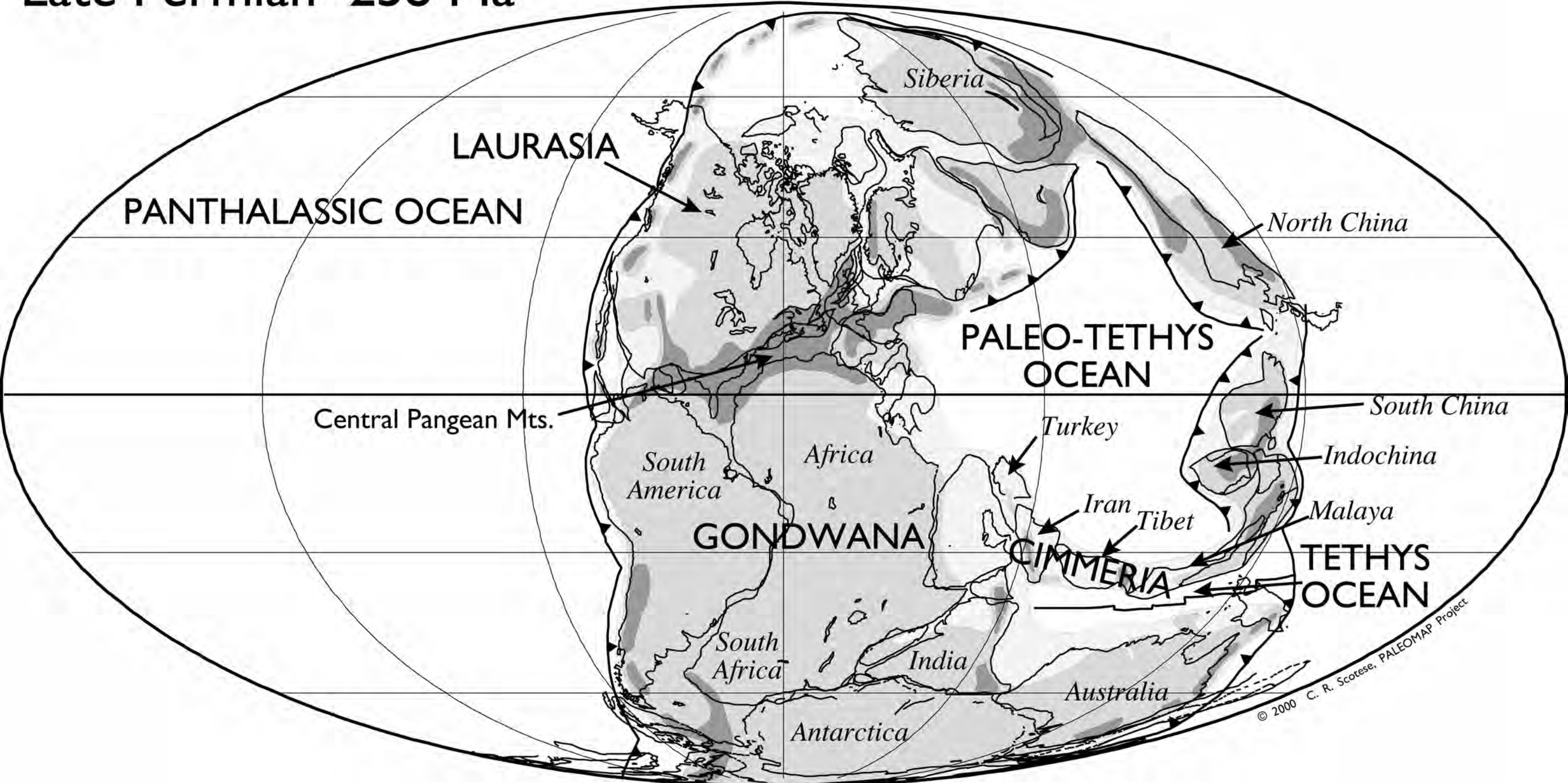
TETHYS OCEAN

Ancient Landmass  
Modern Landmass

Subduction Zone (triangles point in the direction of subduction)  
Sea Floor Spreading Ridge

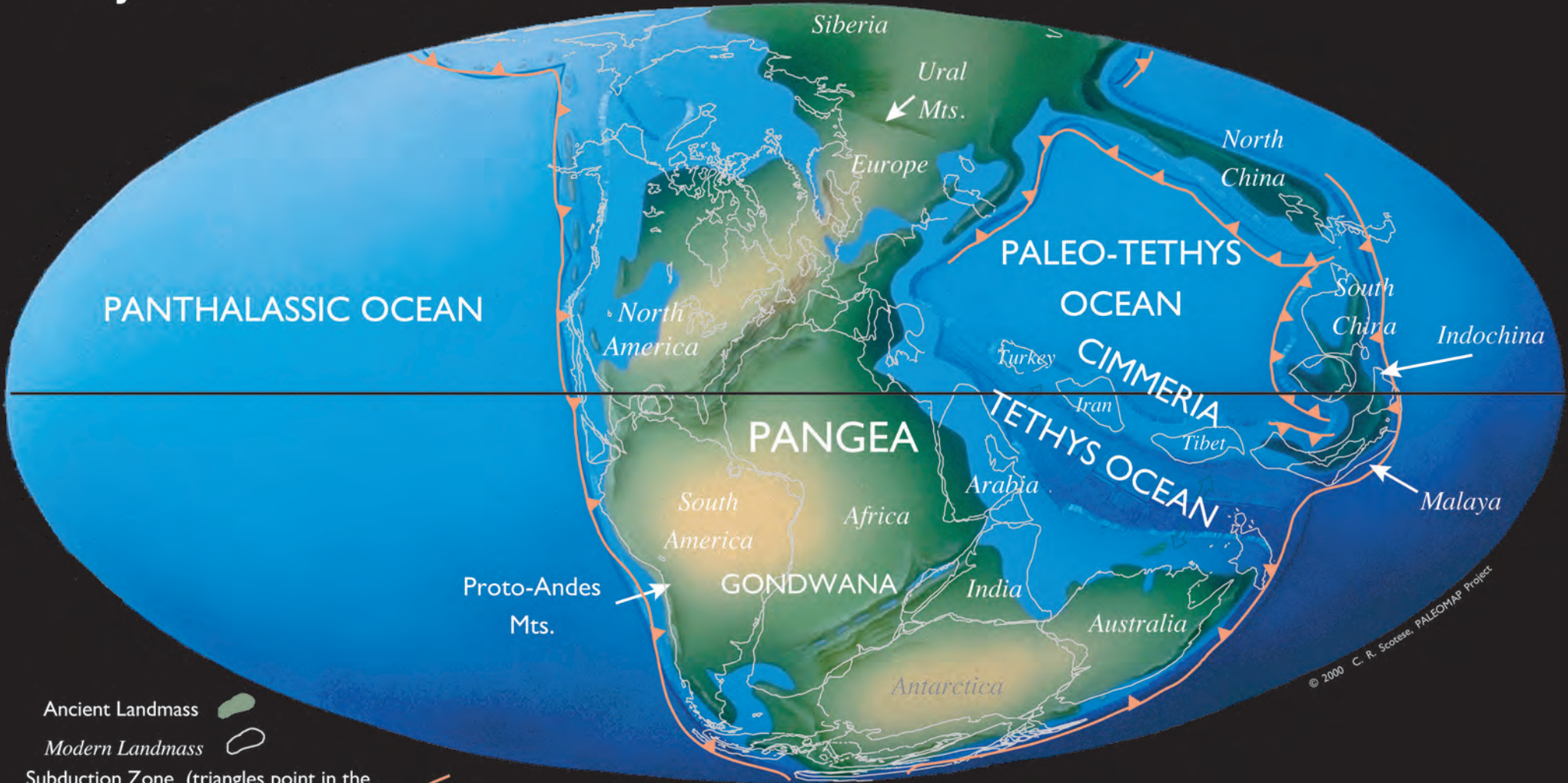
© 2000 C. R. Scotese, PALEOMAP Project

# Late Permian 258 Ma



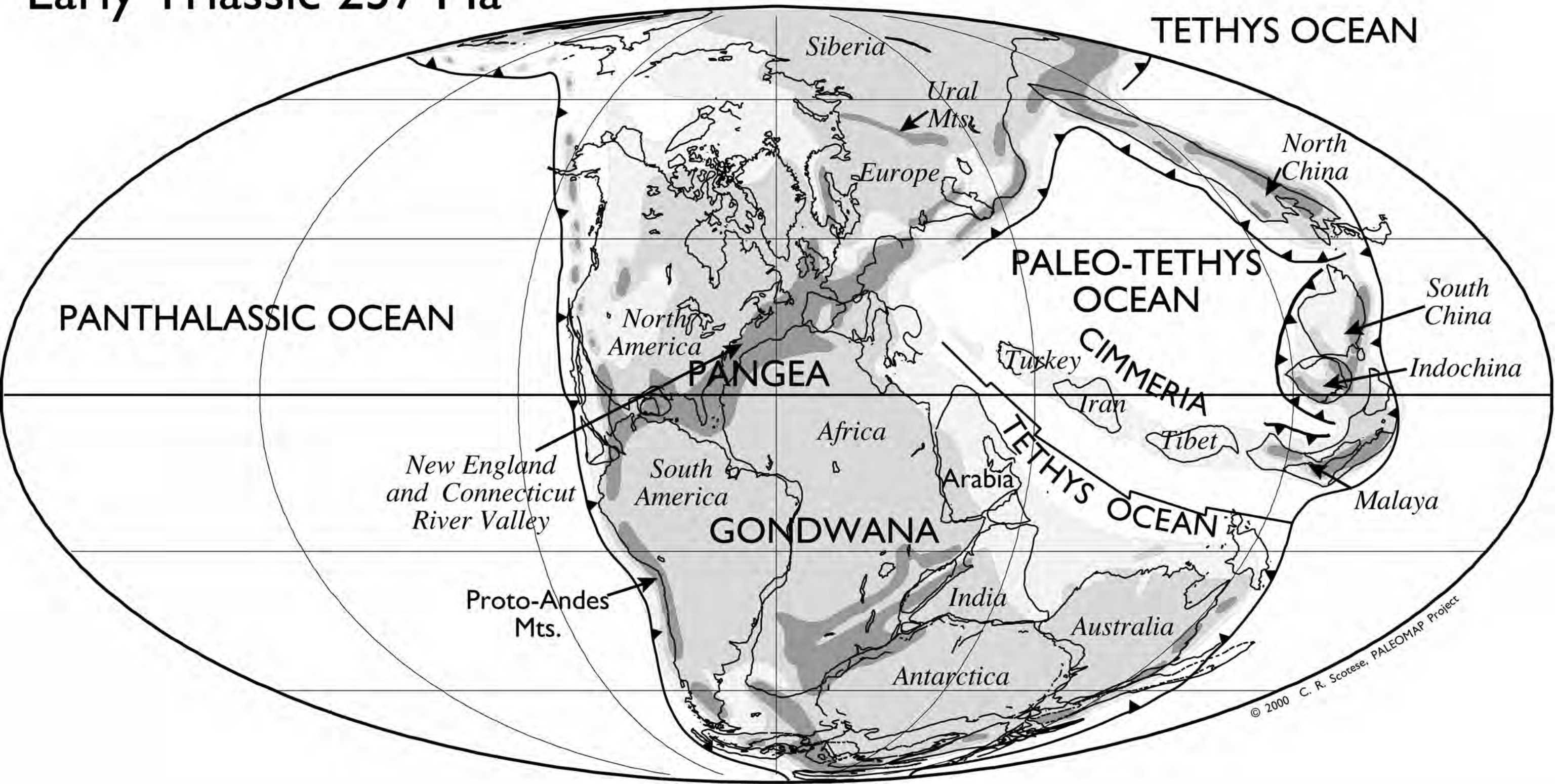


# Early Triassic 237 Ma



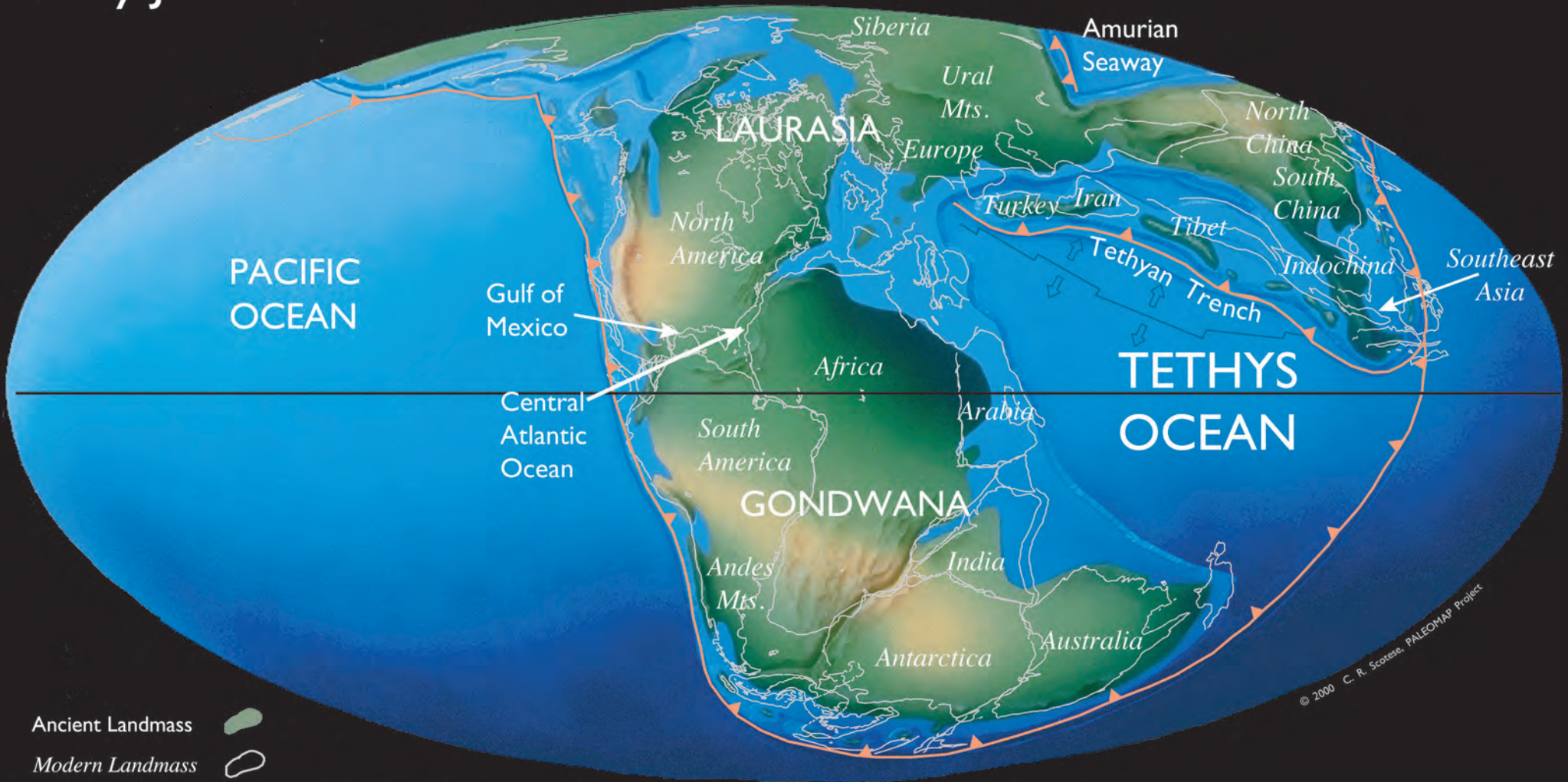
- Ancient Landmass
- Modern Landmass
- Subduction Zone (triangles point in the direction of subduction)
- Sea Floor Spreading Ridge

# Early Triassic 237 Ma





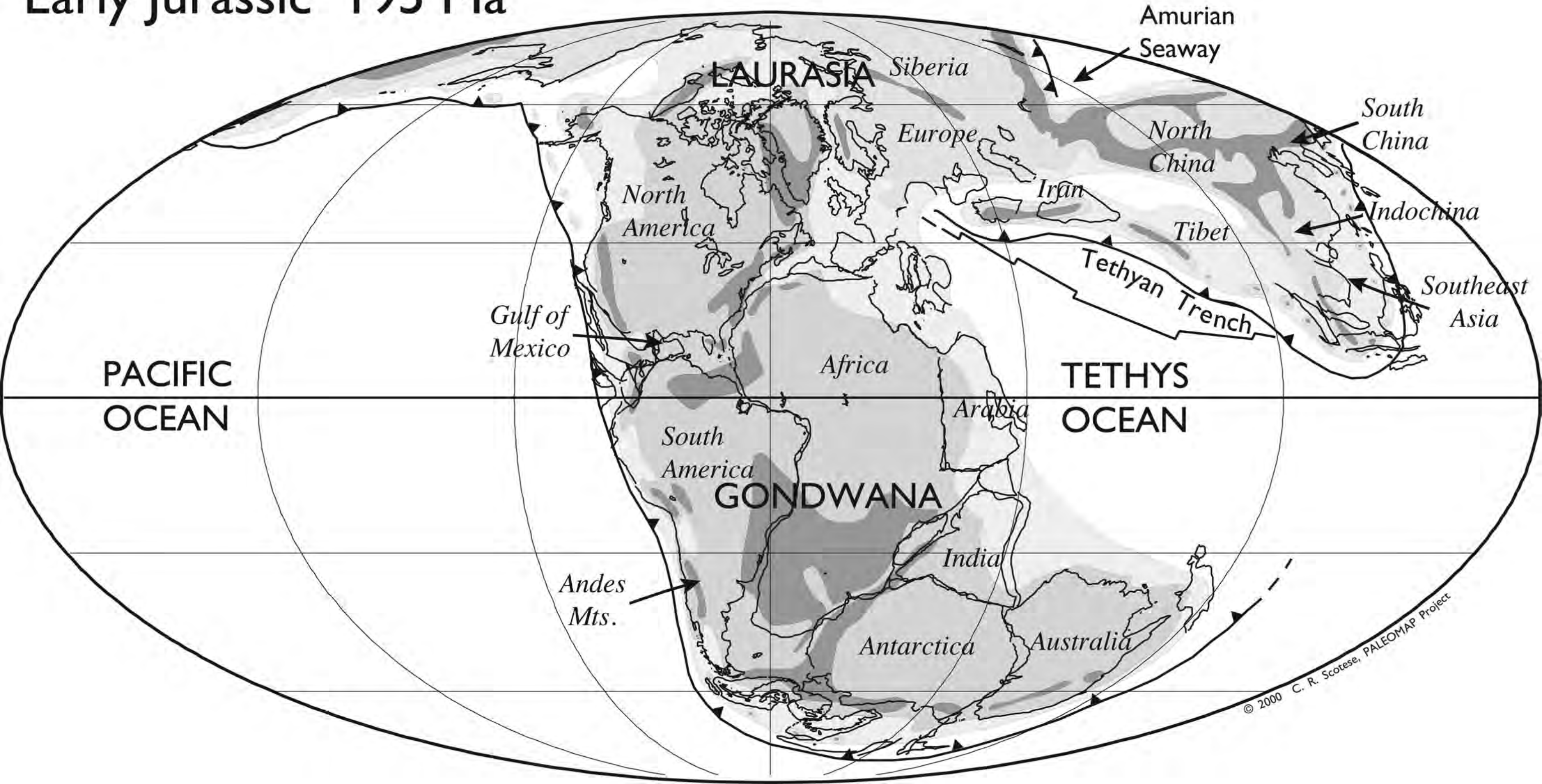
# Early Jurassic 195 Ma



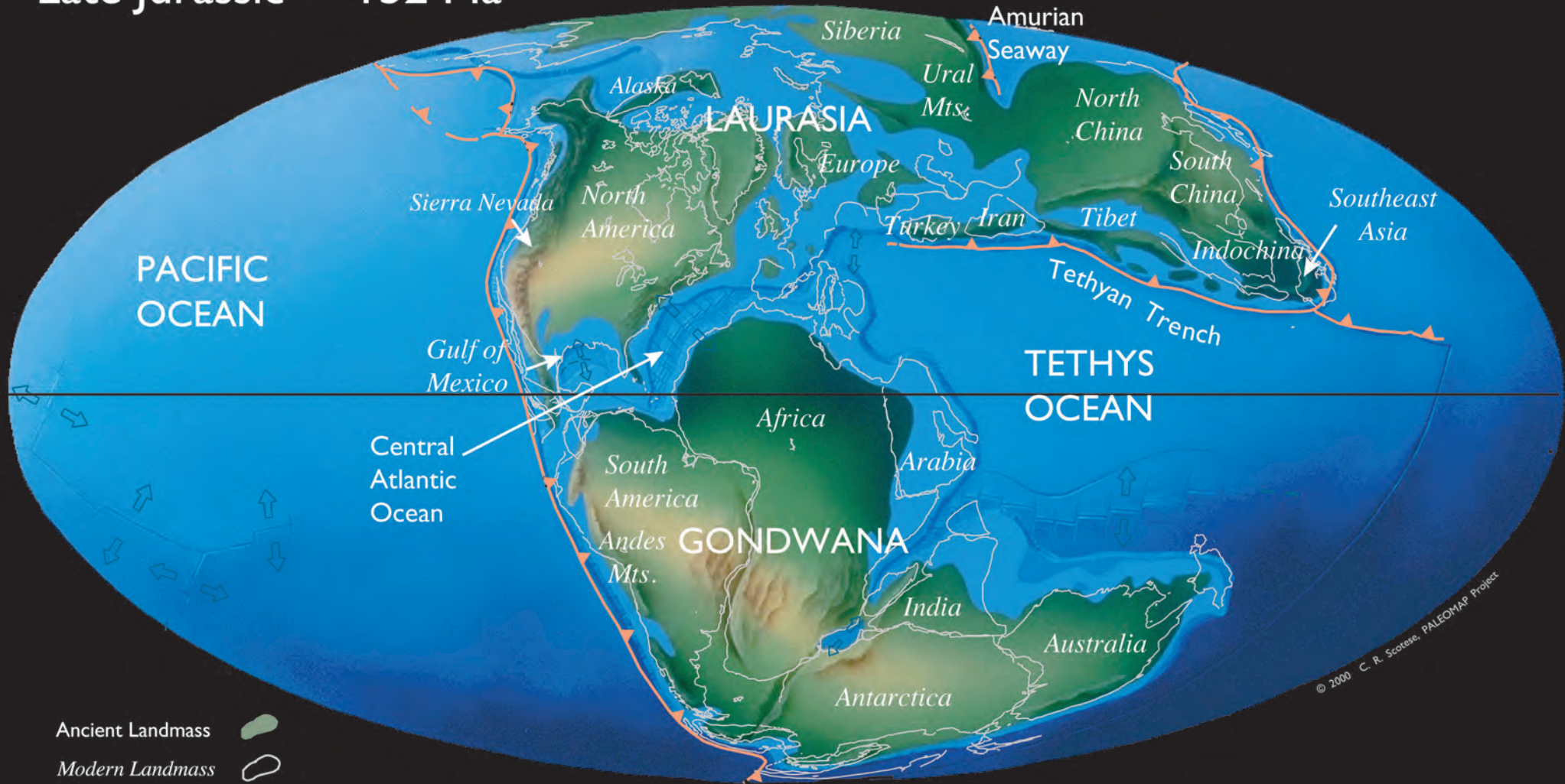
© 2000 C. R. Scotese, PALEOMAP Project







# Early Jurassic 195 Ma



# Late Jurassic 152 Ma

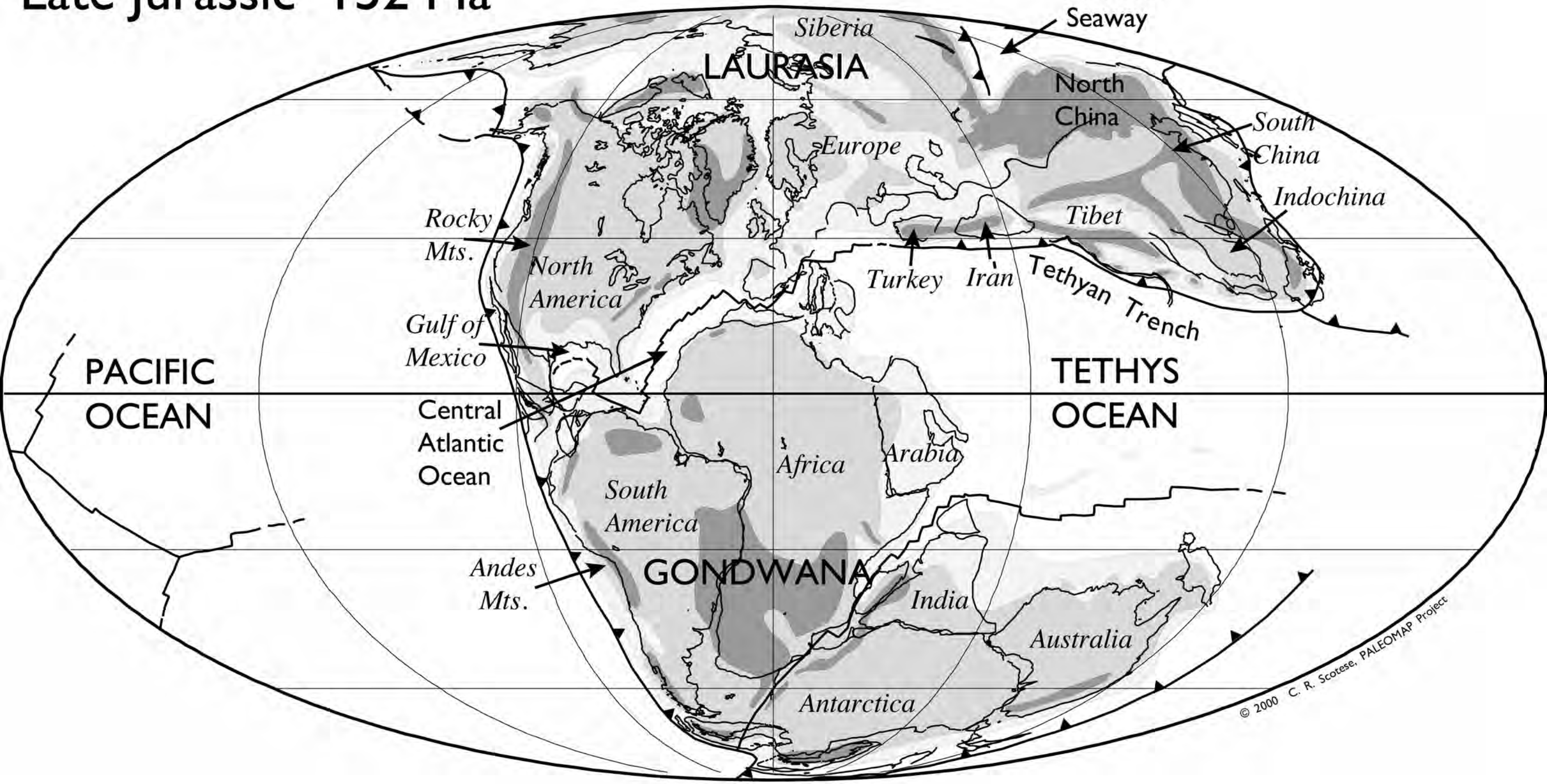


- Ancient Landmass 
- Modern Landmass 
- Subduction Zone (triangles point in the direction of subduction) 
- Sea Floor Spreading Ridge 

© 2000 C. R. Scotese, PALEOMAP Project

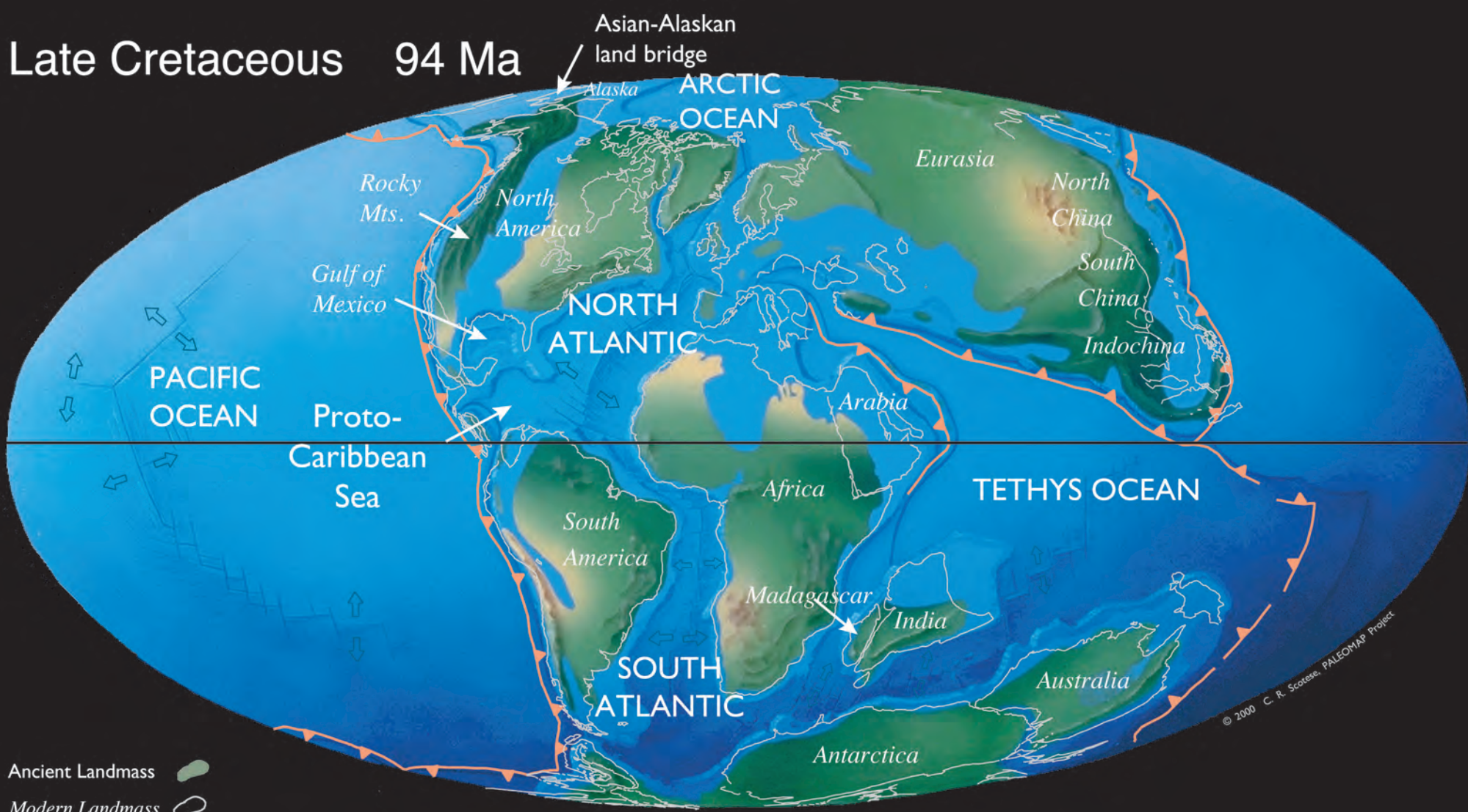







# Late Jurassic 152 Ma



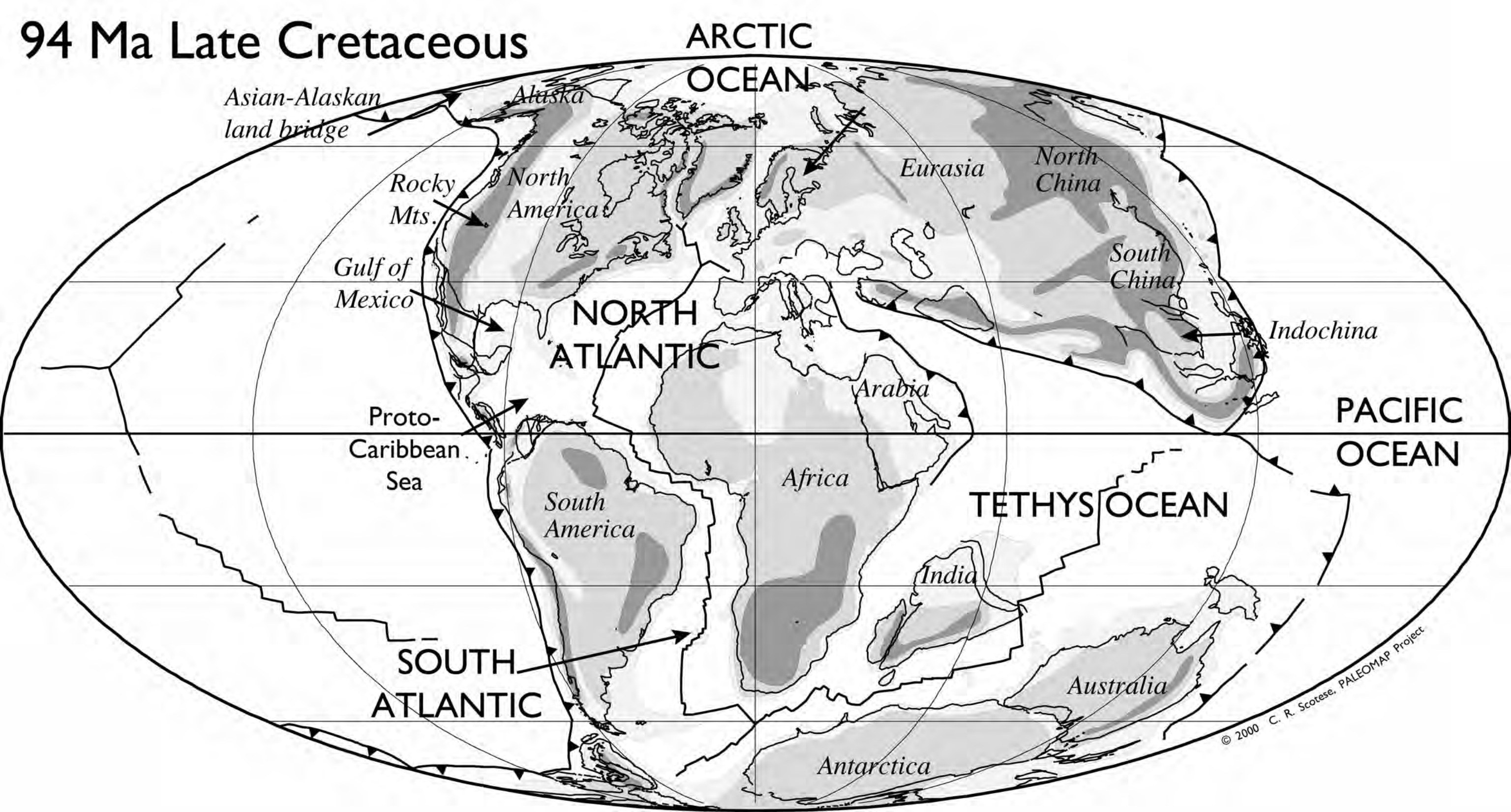


# Late Cretaceous 94 Ma



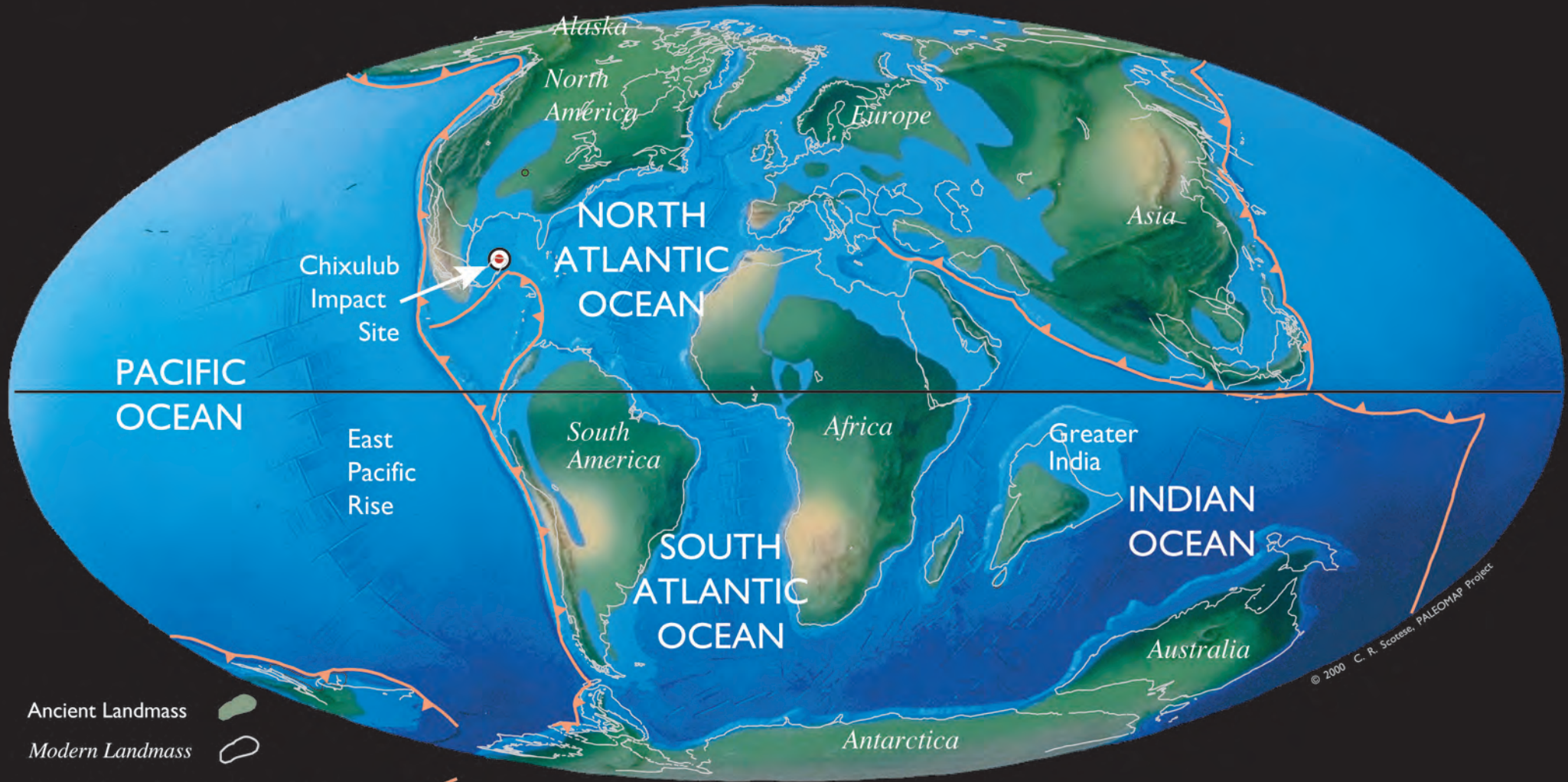
Ancient Landmass   
Modern Landmass   
Subduction Zone (triangles point in the direction of subduction)   
  


# 94 Ma Late Cretaceous




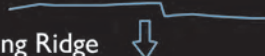




# K/T Boundary 66 Ma

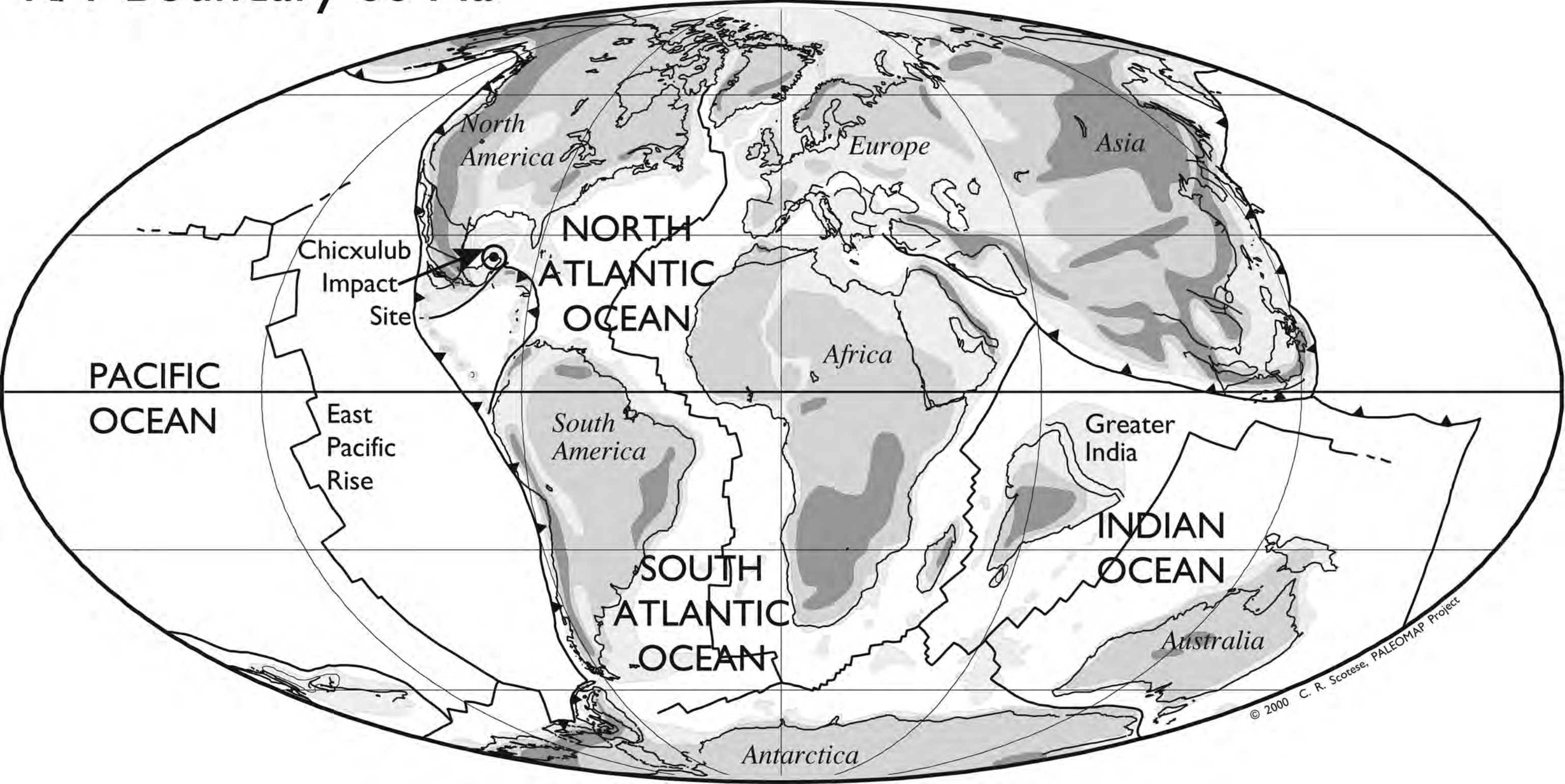


© 2000 C. R. Scotese, PALEOMAP Project

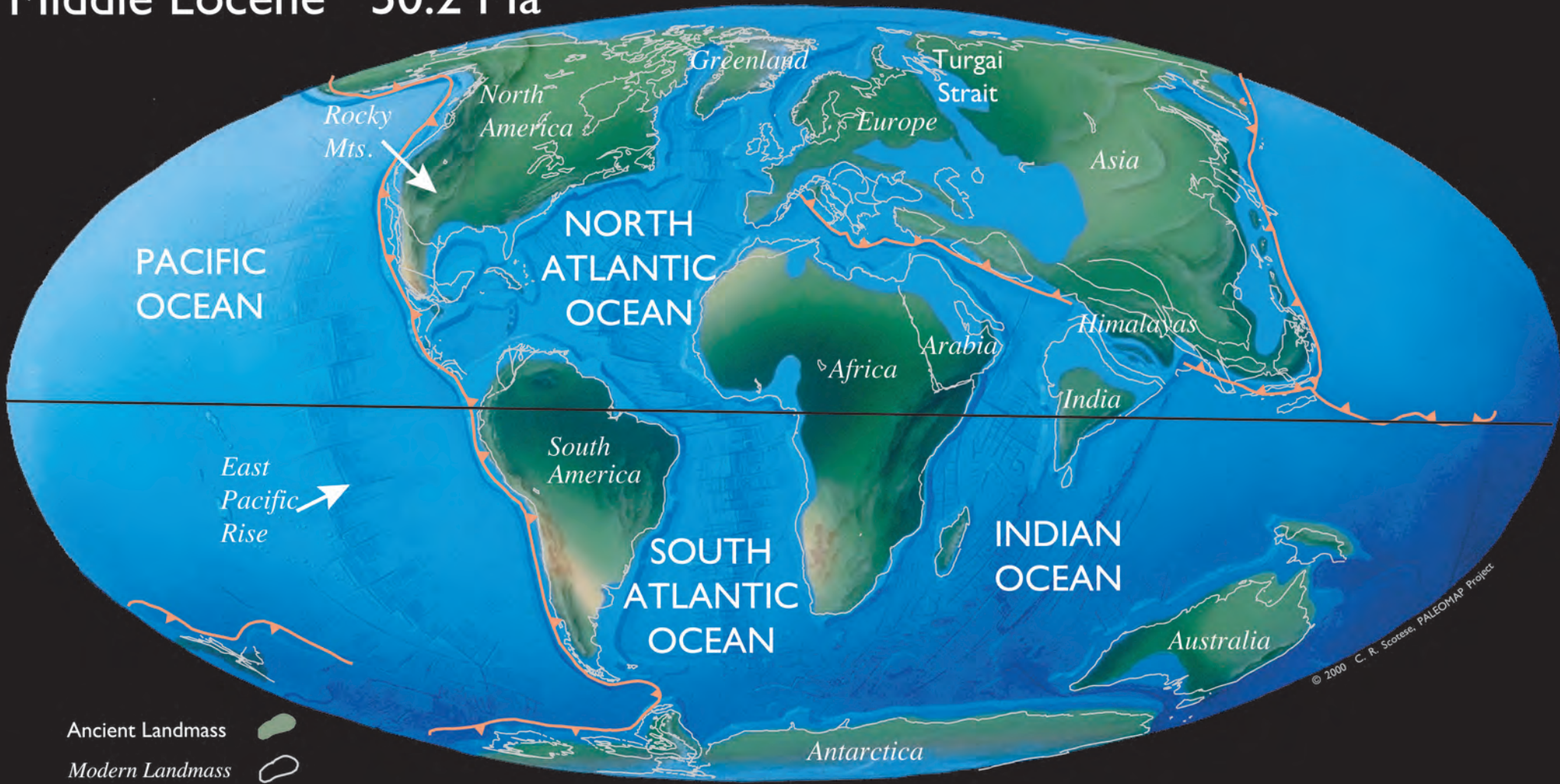
Ancient Landmass   
Modern Landmass   
Subduction Zone (triangles point in the direction of subduction)   
Sea Floor Spreading Ridge 



# K/T Boundary 66 Ma



# Middle Eocene 50.2 Ma



Ancient Landmass



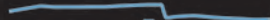
Modern Landmass



Subduction Zone (triangles point in the direction of subduction)



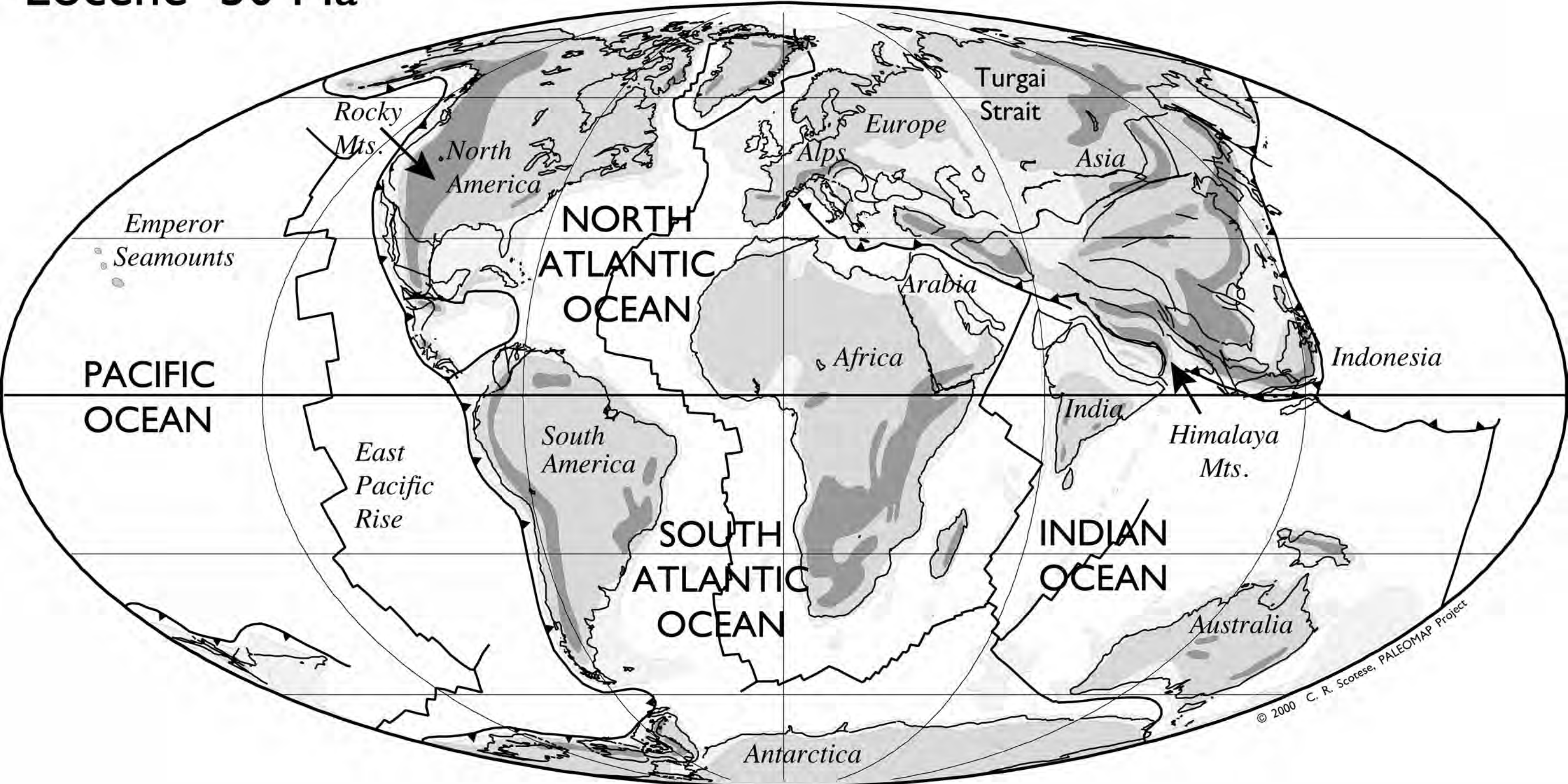
Sea Floor Spreading Ridge



© 2000 C. R. Scotese, PALEOMAP Project



# Eocene 50 Ma





# Middle Miocene 14 Ma



Ancient Landmass



Modern Landmass



Subduction Zone (triangles point in the direction of subduction)

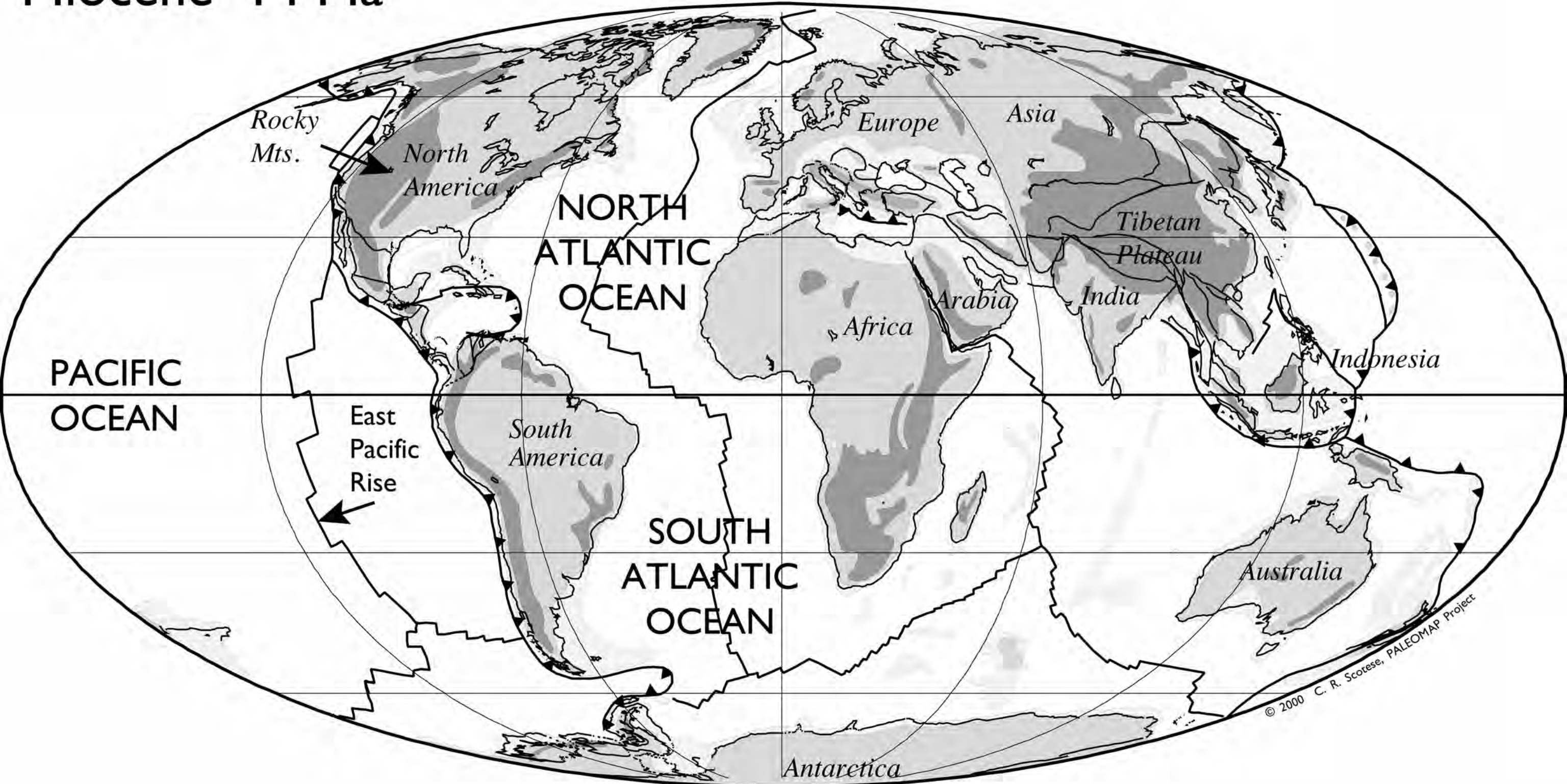


Sea Floor Spreading Ridge



© 2000 C. R. Scotese, PALEOMAP Project

# Miocene 14 Ma




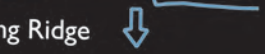


# Last Glacial Maximum 18,000 years ago



Ancient Landmass   
Modern Landmass 

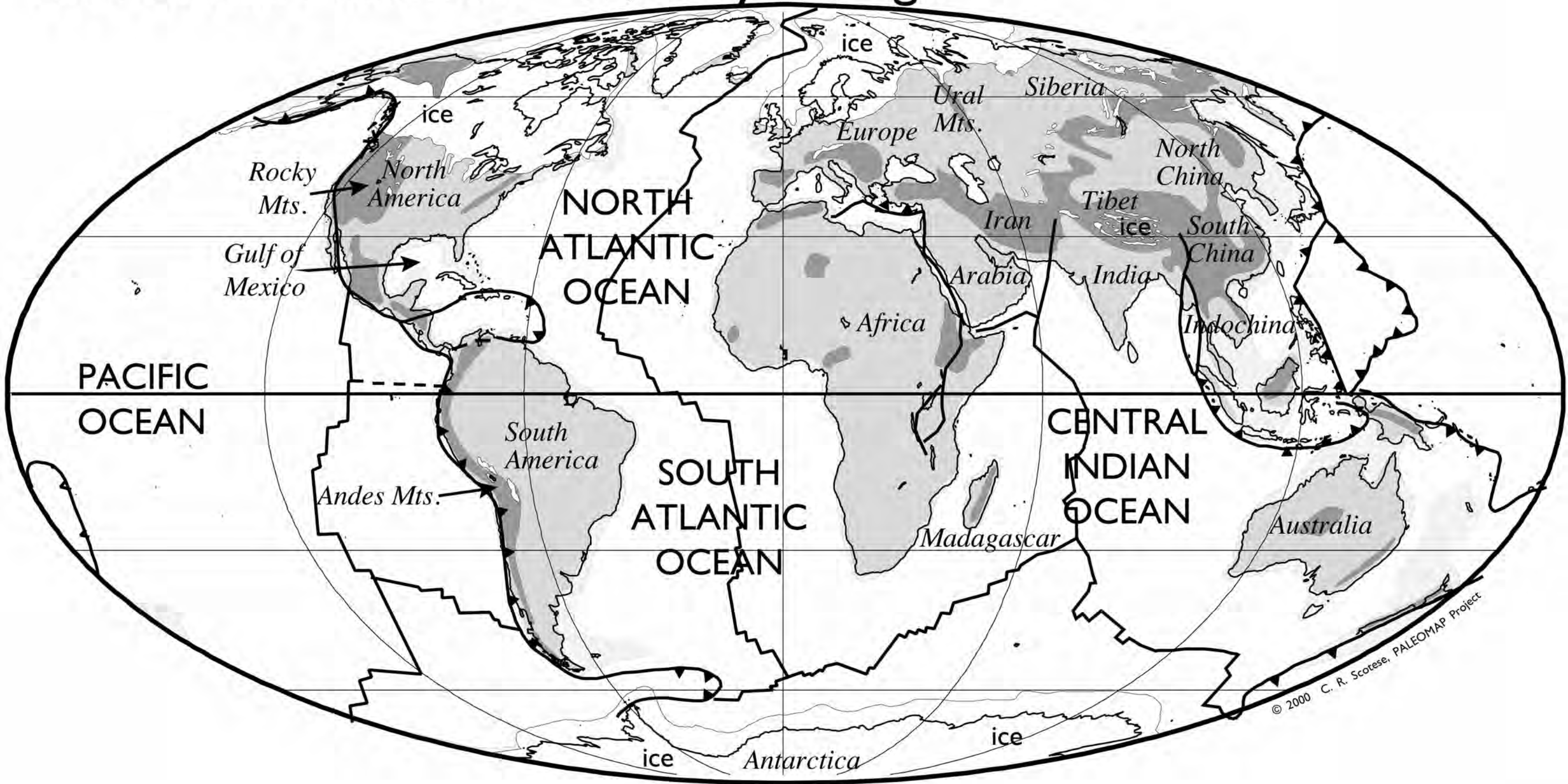
Subduction Zone (triangles point in the direction of subduction) 

Sea Floor Spreading Ridge 

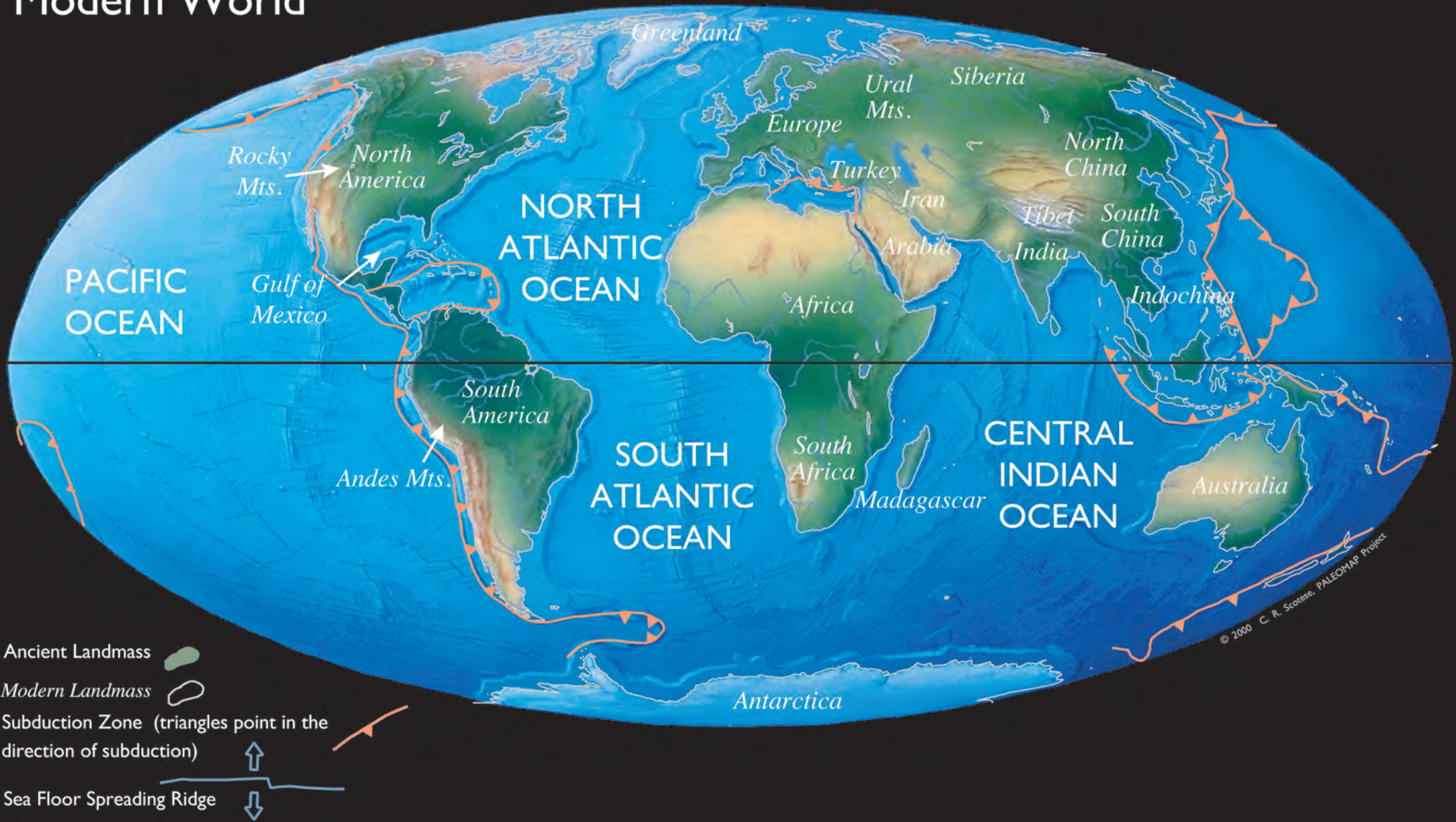
© 2000 C. R. Scotese, PALEOMAP Project



# Last Glacial Maximum 18,000 years ago

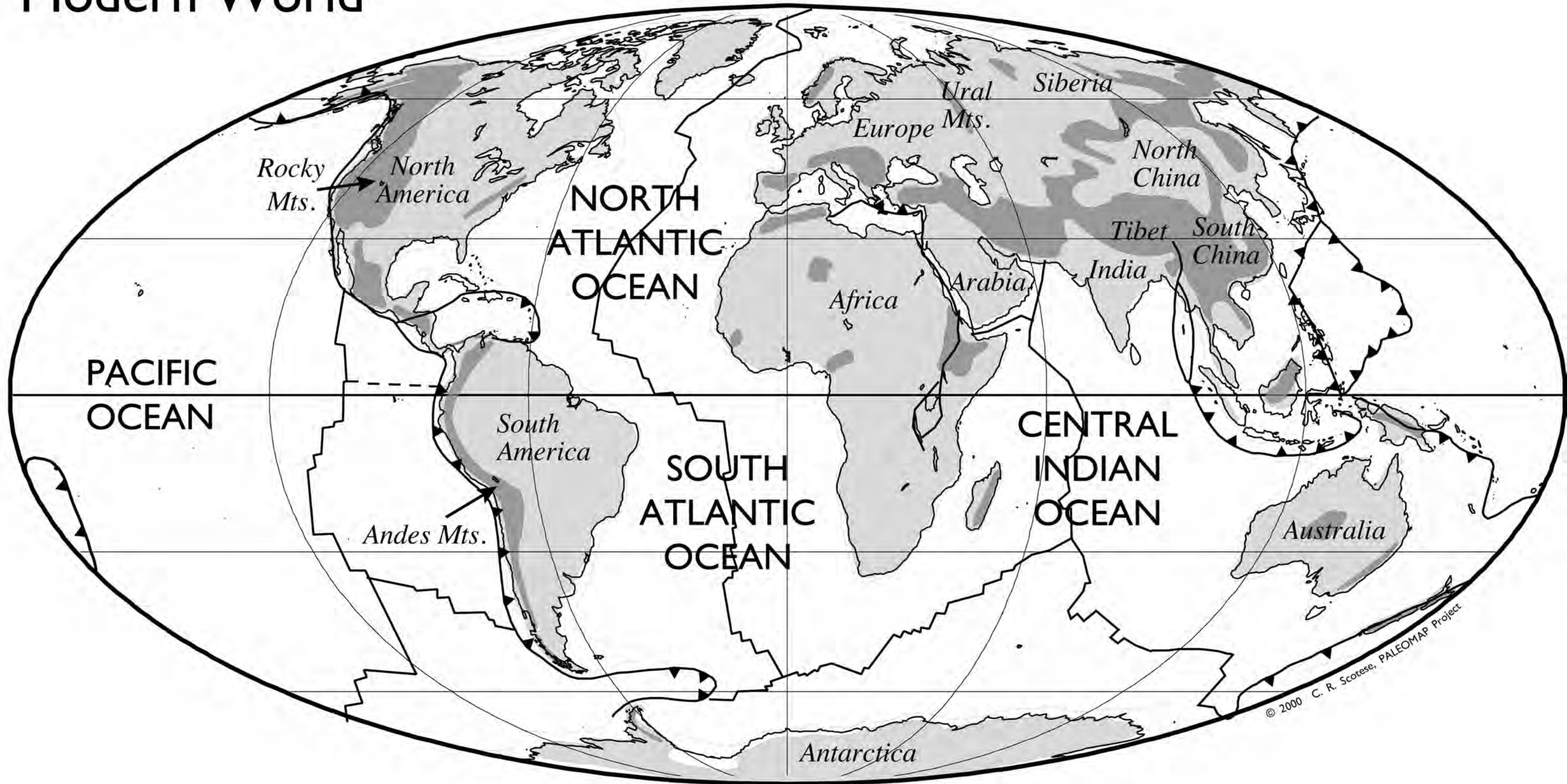


# Modern World



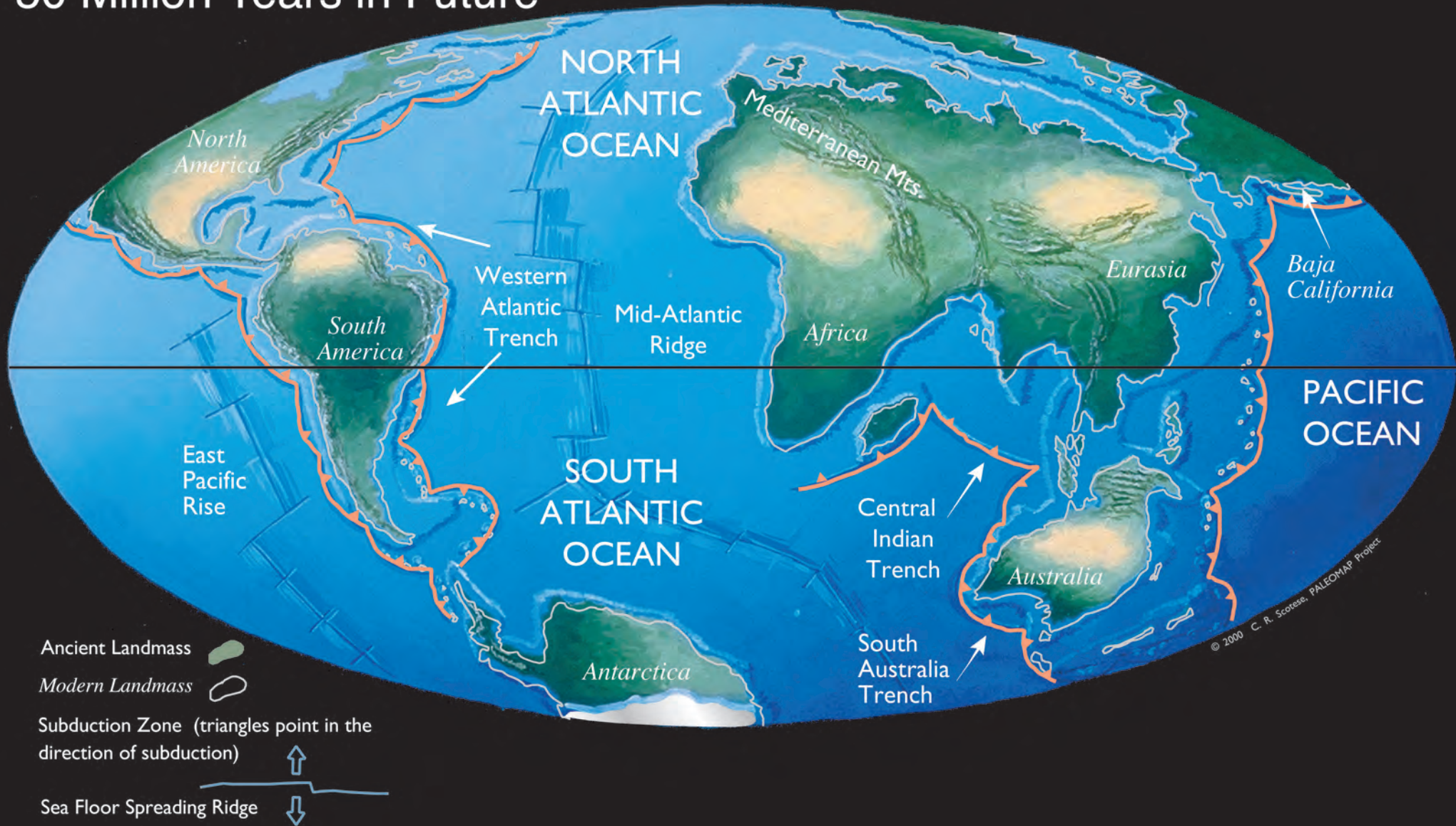


# Modern World

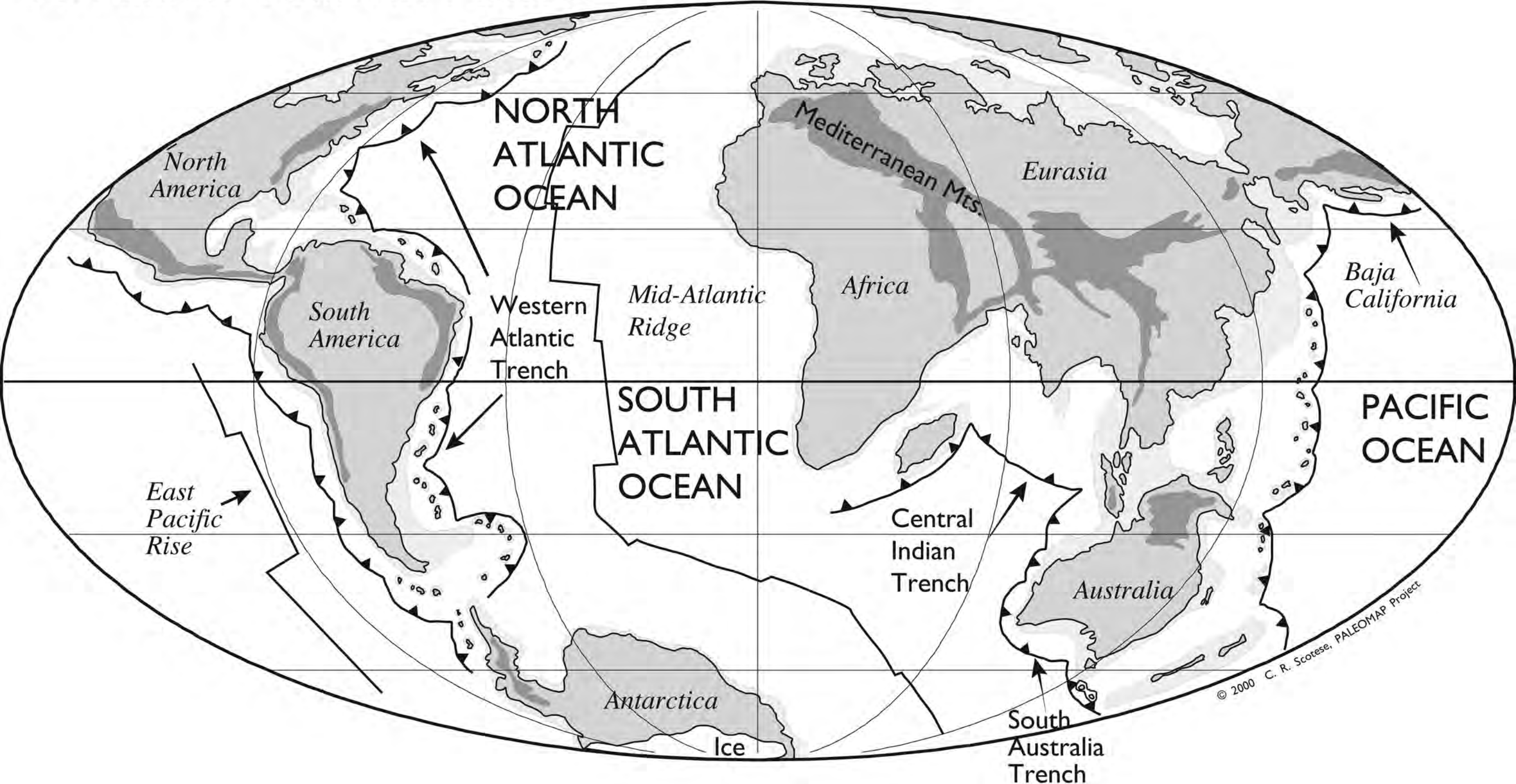




# 50 Million Years in Future







# 50 Million Years in Future





# 150 Million Years in Future

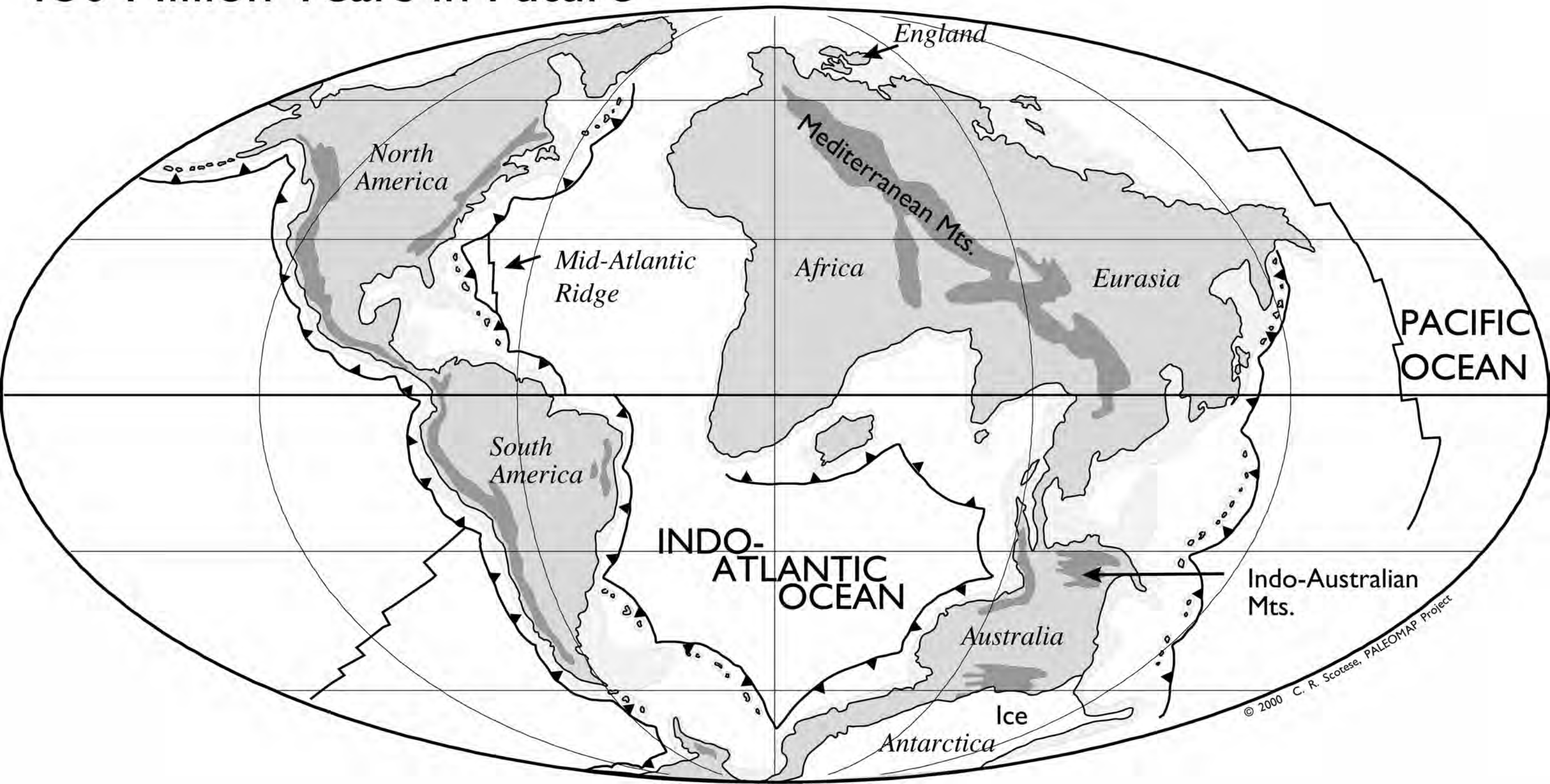


- Ancient Landmass 
- Modern Landmass 
- Subduction Zone (triangles point in the direction of subduction) 
- Sea Floor Spreading Ridge 

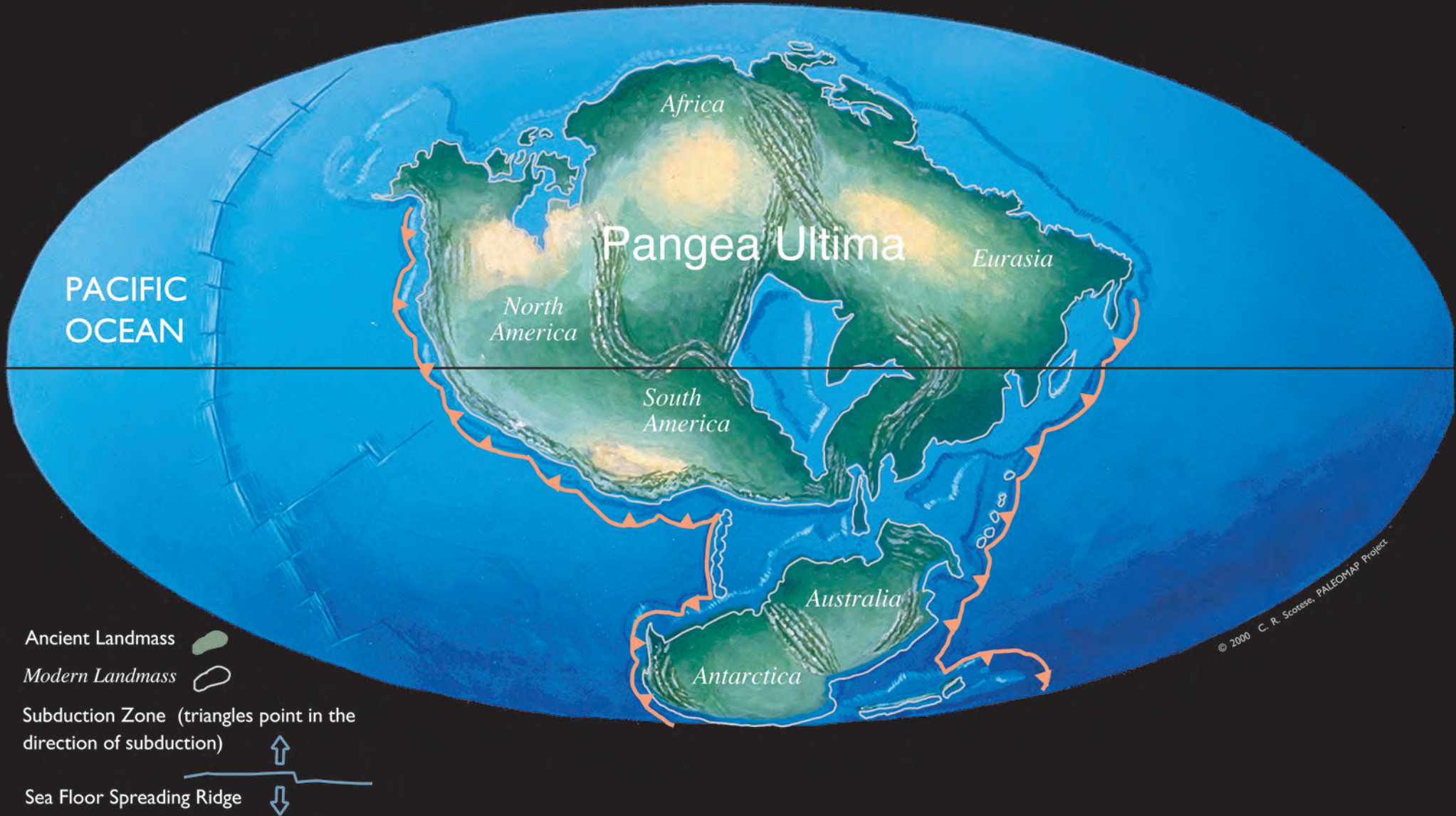
© 2000 C. R. Scotese, PALEOMAP Project



# 150 Million Years in Future



# 250 Million Years in Future





# 250 Million Years in Future

