Chapter 16
Continents and Mountain Ranges

Abstract Continents and ocean basins make up the planet's crust, Earth's outermost layer. Continental areas consist of sialic materials and ocean basins consist of simatic materials, the two main rock types, based on their mineral composition, that make up the Earth's crust. There are several models for naming continents including a seven-continent model and a three-continent model. Both continents and ocean basins have mountain ranges and the continental ones, such as the Alps, Himalayas, Appalachians, and Rockies are better known. The Mid-Atlantic Ridge is most likely the best-known oceanic one. Continental climates are moderated by nearby bodies of water and often form rain-shadows. The continents have drifted to their present locations from a supercontinent called Pangaea that straddled the equator at times past. The mechanism for drifting continents is the concept of Harry Hess' sea-floor spreading that gave rise to the theory of plate tectonics.

Keywords Sial • Sima • Continent • Ocean • Basin • Landmass • Isthmus • Suez • Asia • Europe • Australia • Africa • Granite • Basalt • Gondwana • Laurasia • Pannotia • Eurasia • Supercontinent • Pangaea • Rodinia • Drift • Hess • Spreading • Islands • Arcs • Appalachians • Rockies • Alps • Guyots • Seamounts • Transantarctic • Asthenosphere • Convection • Caucasus

Things to Know

The following is a list of things to know from this chapter. It is intended, as it is in each chapter, to serve as a guide to points of emphasis for the student to keep in mind while reading the chapter. Before finishing with this and each chapter, the "Things to Know" should be understood and can be used for review purposes. The list may not include all of the terms and concepts required by the instructor for this topic.

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Things to Know	
Continents	1.1 Billion
Sima	Eurasia
Rodinia	Seven Continent Model
Isthmus of Suez	Sial
Sea-Floor Spreading	Pangaea
Ocean Basins	Harry Hess
Transantarctic Mountains	Gondwana
Southern Alps	Beartooth
Plate Tectonics	Appalachians
Three Continent Model	Ural Mountains
Alfred Wegener	Six Continent Model

16.1 Introduction

A continent is a large landmass on Earth usually separated by ocean or other body such as a mountain range. In the seven-continent model (Fig. 16.1), the major continents are North America, South America, Asia, Africa, Antarctica, Europe, and Australia. North America and South America are separated by the Isthmus of Panama, Europe and Asia are separated by the Ural Mountains, Africa is separated from Europe by the Mediterranean Sea, Asia from Africa by the Isthmus of Suez. In geology and geography, Europe and Asia are combined into one continent, Eurasia which makes a six-continent model. The distribution of continents across

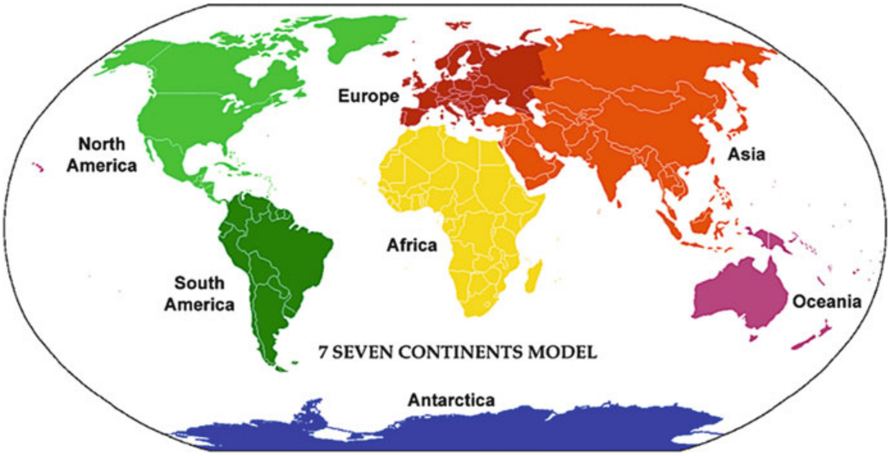

Fig. 16.1 *Color-coded map* showing the various continents. Similar *shades* exhibit areas that may be consolidated or subdivided (From Wikipedia, Public Domain)

the surface of Earth is very important for their effects on world-wide climate. If all continents are together straddling the equator the global climate is much different than it is when the continents are mainly in the Northern Hemisphere or migrating towards the poles and we know that in the geologic past continents have drifted across the face of the planet.

From a geological or physical geography perspective, a continent may be extended beyond the confines of continuous dry land to include the shallow, submerged adjacent area, the continental shelf and continental slope and the islands on the shelf as they are geologically part of the continent. From this perspective the edge of the continental shelf and continental slope represent the true edge of the continent, as shorelines vary with changes in sea level. In this sense the islands of Great Britain and Ireland are part of Europe, while Australia and the island of New Guinea together form a continent.

There are other definitions of continents such as the three-continent model: Eurafrasia (consisting of Africa, Asia and Europe), America (consisting of North America and South America), and Oceania (consisting of Australia, New Zealand, Melanesia, Micronesia, and Polynesia). The six-continent model combines Europe and Asia into one continent (Eurasia).

The positions of continents relative to each other, the equator, the poles, and the sea are all important as they relate to the climate of each at any point in time. The configuration of each continental land mass is also important as high-standing mountains have a climate that is different from adjacent lowlands. The proximity to large bodies of water is important climatically as coastal areas have climates directly affected by adjacent or near-by seas or other large bodies of water.

Continents that we see on maps today are not in the same places as they have been in the past. A map produced 300 million years ago would look much different than the map produced today.

16.2 Continental Drift

A German meteorologist and amateur geologist, Alfred Wegener, in the early part of the twentieth century (1912), first proposed that all of Earth's continents had once been joined in a single supercontinent. He published his ideas for this supercontinent in a book called *Die Entstehung der Kontinente und Ozeane* ("The Emergence of the Continents and Oceans"). The idea that South America and Africa had once been joined had first been proposed in the 1500s, shortly after the first maps of the world were published, but the idea was formalized and evidence for it first cited by Wegener.

Wegener mentioned structures shared by South America and Africa and other evidence for his supercontinent but his ideas were largely ignored by the scientific community at the time. Wegener proposed that the supercontinent had broken apart by the centrifugal force exerted by the Earth spinning on its axis of rotation. This idea was ridiculed by his fellow scientists because the centrifugal force is not great enough to separate continents. Also, geologists and especially geophysicists were

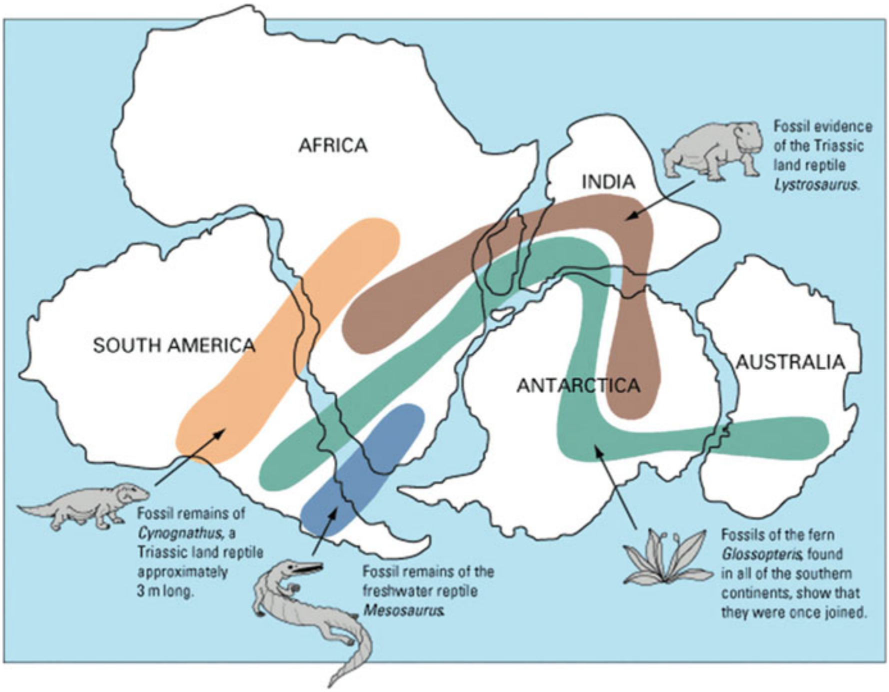

Fig. 16.2 Evidence of continental drift from the fossil record (USGS, Public Domain)

adamantly opposed to the idea of continental masses plowing through the rigid crust to move from place to place.

It wasn't until a mechanism was proposed and tested and voluminous evidence acquired, such as that illustrated in Fig. 16.2, that the concept of continental drift was accorded legitimacy by the scientific community. The fossil organisms shown in Fig. 16.2 were not able to swim or be carried over vast expansive areas of open ocean that exist today.

The mechanism for continental drift that was lacking during Wegener's time was finally conceived by a professor at Princeton University, Harry Hess, as we've seen earlier in this text.

16.3 Harry Hess and Sea-Floor Spreading

Harry Hess (1906–1969) has been previously mentioned in this text as the source of the concept of sea-floor spreading. His work set the stage for the later idea of Plate Tectonics. He served in the U.S Navy in WWII and with the blessing of his crew was able to survey the ocean floor of the Pacific Ocean basin with echo sounding equipment between his ship's battles.

Hess formulated a hypothesis about a spreading sea floor in 1959 in an informal manuscript that was widely circulated among his colleagues. It was later formally published (1962) in a paper entitled “History of Ocean Basins” which was one of the most important and groundbreaking contributions in the development of the theory of Plate Tectonics and of Earth science in general. Hess built upon the work of an English geologist, Arthur Holmes (1890–1965), who worked in the early to middle parts of the twentieth century. Holmes championed the concept of continental drift and the sea-floor spreading concept of Hess.

In Hess’ 1962 paper, he described how seafloor spreading worked; molten rock (magma) oozes from the Earth’s interior along the mid-oceanic ridges, creating new seafloor that spreads away from the active ridge and eventually sinks into the deep ocean trenches. The mechanism that causes this is convection cells in the Earth’s mantle. Convection cells bring molten rock to the surface at mid-ocean ridges and the seafloor is forced apart and moved away from the ridges.

At the time of Hess’ paper, there were certain questions about the seafloor that were still unanswered. It had been discovered that the ocean basins were not as old as they had been thought to be. Geologists had long thought that the ocean basins would yield sediments that would provide evidence for the beginning of time on Earth, the Earth’s origin (about 4.54 billion years ago). This was not the case and Hess reasoned that sediment had been accumulating on the ocean floor for only about 300 million years. Hess estimated that it took that long for the ocean floor to move from the mid-ocean ridges to the oceanic trenches near the continents. Later sampling and age dating of oceanic rocks would prove Hess’s estimates correct.

Hess’ idea received the expected resistance from the numerous conservatives in the scientific community because geologists were still skeptical about a mechanism, although Hess knew that the oldest fossils found at that time on the seafloor were only about 180 million years old. He proposed that the mechanism for sea-floor spreading was new crust formed at the mid-ocean ridges that forced the seafloor to move to the trenches. Many still clung to the belief that continents and ocean basins had been too brittle for them to move great distances, as was called for by the sea-floor spreading concept, and the earlier concept of drifting continents by Wegener. After all, when struck by a hammer or other tool, most rocks shatter. Earlier ideas on continental drift had the continents plowing through the oceanic crust to their present locations and most geologists and geophysicists knew that this was simply not possible.

Hess was aware that there were limited ways to test his hypothesis, but later geophysical studies confirmed that oceanic crust was disappearing (subducting) into the Earth’s oceanic trenches. Hess, unlike Wegener, lived to see the confirmation of his hypothesis and it resulted in the concept of Plate Tectonics that revolutionized the Earth sciences at the time. It has been described as a paradigm shift in Earth Science. It has caused geologists around the world to look at rocks and Earth history in an entirely different way than they had before.

Hess also discovered hills on the seafloor that had flat tops. These he called guyots, which are flat-topped volcanic hills that were built from the seafloor to the surface of the ocean when they were formed and had their tops cut off (eroded) by wave action and later sank to the bottom. Other hills on the sea floor were called seamounts. The guyots with their flat tops slowly sank below the surface under their own weigh (the geology building at Princeton University at the time was named Guyot Hall in honor of Harry Hess and his ground-breaking research).

16.4 Plate Tectonics

Plate tectonics is the theory of Earth history which has as its underlying concept the idea of continental drift. The concept evolved from evidence gathered from the continents and from the ocean basins of Earth. Plate tectonic theory says that the Earth's crust consists of relatively thin plate-like continental crust "floating" on a plastic-like substrate called the asthenosphere (see Fig. 16.5 below). Figure 16.5 shows the subduction of oceanic crust beneath a continental crust and the volcanoes at the surface. Movement of oceanic crust is due to the asthenosphere which is the upper part of Earth's mantle. The asthenosphere behaves as a plastic layer and moves because of convection cells in the mantle.

Oceanic plates (basaltic or simatic) are generally denser than continental plates (granitic or sialic). When an oceanic plate and a continental plate collide, the denser oceanic plate sinks beneath the continental plate. The oceanic plate is subducted beneath the continental plate. Geologists think that the oceanic plate is pulled down beneath the continental plate by an "arm" of a convection cell.

Figure 16.3 shows all of Earth's plates as they were in the supercontinent of Pangaea before its breakup. The red arrows indicate directions of movement of the plates as they broke apart.

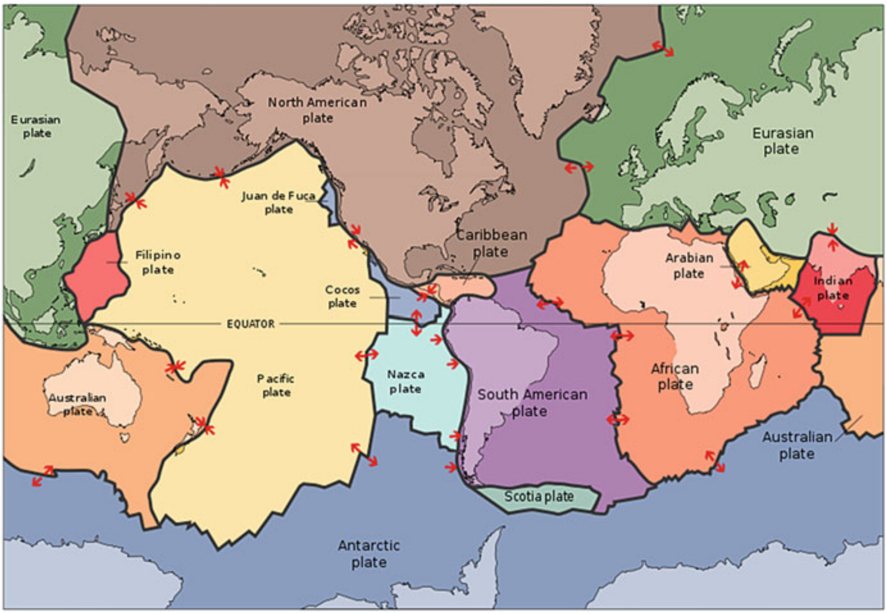

Fig. 16.3 The key principle of plate tectonics is that the lithosphere exists as separate and distinct tectonic plates, which float on the fluid-like (visco-elastic solid) asthenosphere. The relative fluidity of the asthenosphere allows the tectonic plates to undergo motion in different directions. This map shows 15 of the largest plates. Note that the Indo-Australian Plate may be breaking apart into the Indian and Australian plates, which are shown separately. *Red arrows* indicate relative plate movements (USGS, Public Domain)

Essential concepts of plate tectonic theory are the following:

1. Plate boundaries;
2. Subduction zones;
3. Rates of plate movement;
4. Mid-ocean ridges;
5. Hot spots;
6. Sea-floor spreading;
7. Magnetic reversals;
8. Oceanic trenches;
9. Island arcs;
10. Asthenosphere;
11. Convection in the Earth's mantle;
12. Differences between oceanic and continental crust).

16.4.1 Types of Plate Boundaries

Four types of plate boundaries exist, characterized by the way the plates move relative to each other. They are associated with different types of surface expression. The different types of plate boundaries are:

1. **Transform boundaries** – occur where plates slide or grind past each other along transform faults.
2. **Divergent boundaries** occur where two plates slide away from each other. Mid-ocean ridges (e.g., Mid-Atlantic Ridge) and active zones of rifting (such as Africa's Great Rift Valley) are both examples of divergent plate boundaries (Fig. 16.3).
3. **Convergent boundaries** (or active margins) occur where two plates slide towards each other commonly forming either a subduction zone (if one plate moves underneath the other) or a continental collision (if the two plates contain continental crust). Deep marine trenches are typically associated with subduction zones. Examples of this are the Andes mountain range in South America and the Japanese island arc.
4. **Plate boundary zones** occur where the effects of the interactions are unclear and the broad belt boundaries are not well defined.

Types of plate boundaries are illustrated in Fig. 16.5 below.

Plates move relative to each other on the order of millimeters a year, or at the most a centimeter a year. Their rate of movement varies but averages from about 10 to 160 mm per year. Some plates move slowly, then bound wildly at about a centimeter of movement all at once. This is thought to be due to the elastic nature of the plate substrate and perhaps is related to the elastic rebound theory of earthquakes.

Plate boundaries are where most crustal activity takes place. Around the Pacific Ocean is the "Circum-Pacific Ring of Fire" so called because of the earthquake and

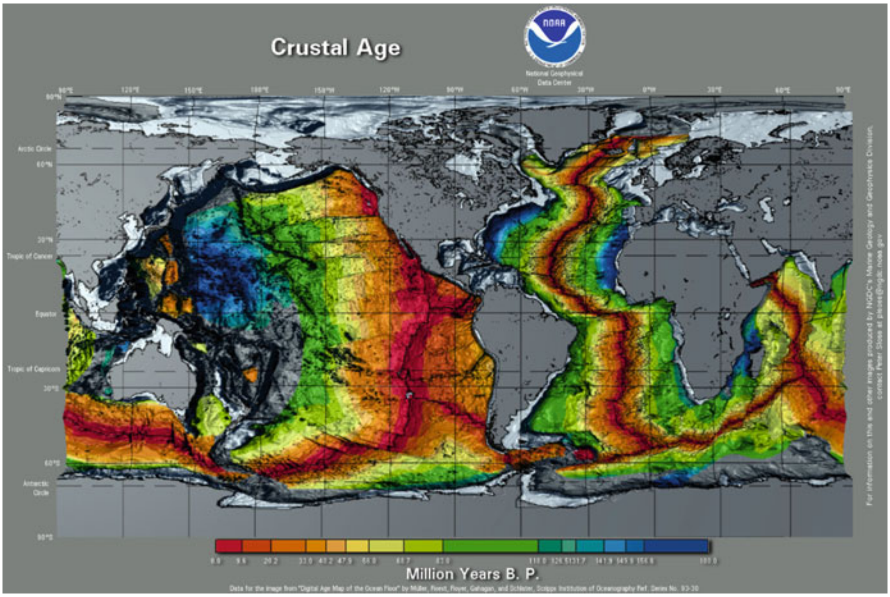

Fig. 16.4 Features of the ocean basins showing relative ages of the ridges and floors of the ocean basins (NOAA, Public Domain)

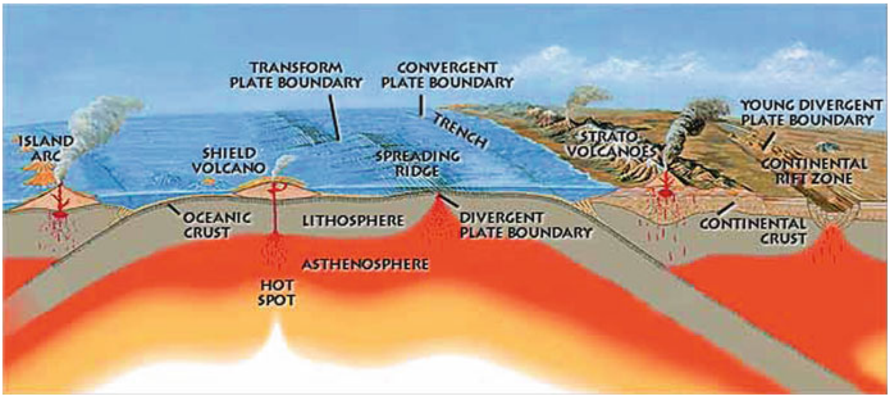

Fig. 16.5 Different types of plate boundaries (USGS, Public Domain)

volcanic activity on its margins. The figure below (Fig. 16.6) shows the distributions of earthquakes and volcanoes on plate boundaries of the world.

Earthquakes and volcanoes are not randomly scattered across the surface of Earth but occur in distinct areas; the circum-Pacific, the Mediterranean, Indonesia, Japan,

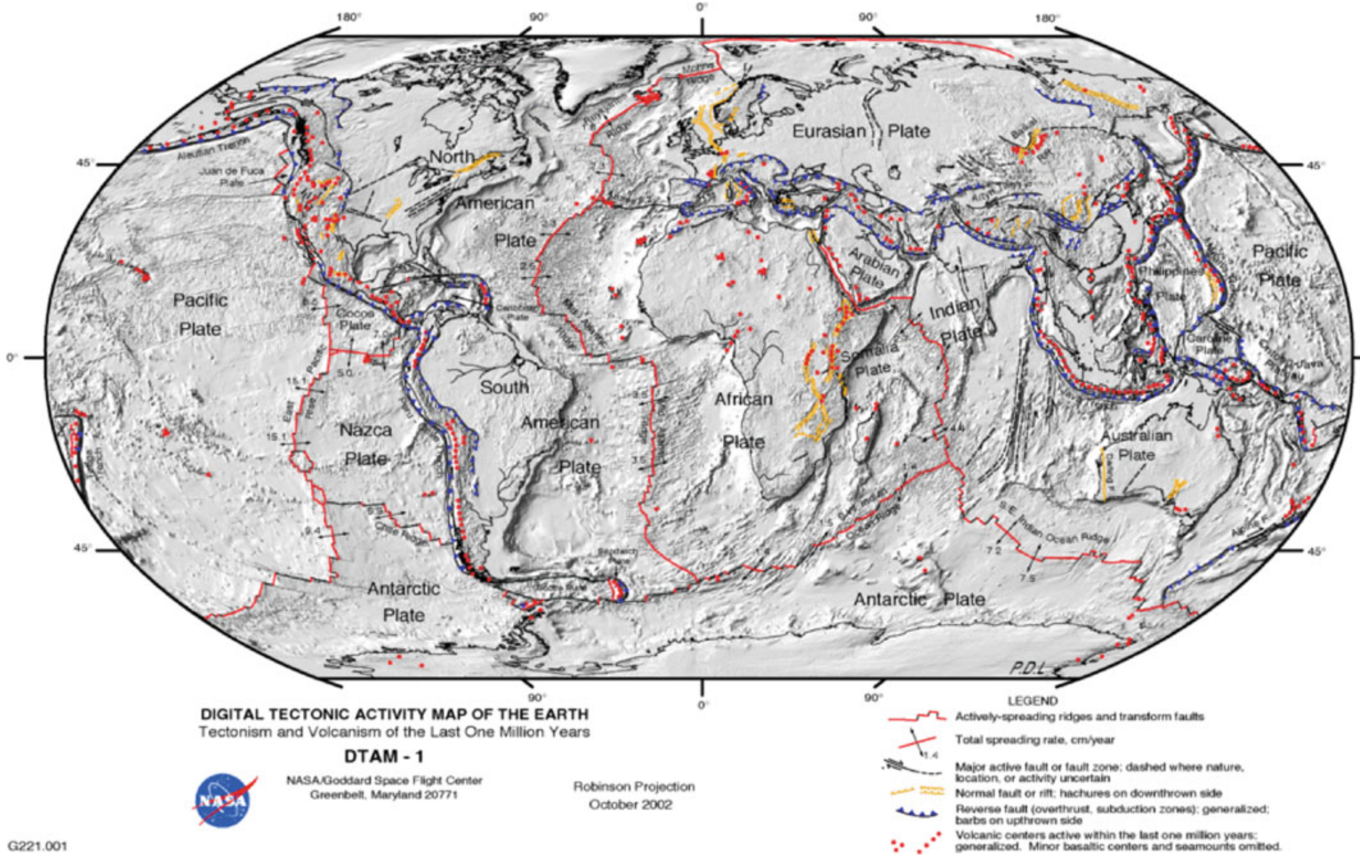

Fig. 16.6 Crustal plate boundaries showing the locations of earthquakes and the "ring of fire" around the Pacific Ocean Basin (From http://csep10.phys.utk.edu/astr161/lect/earth/evidence.html)

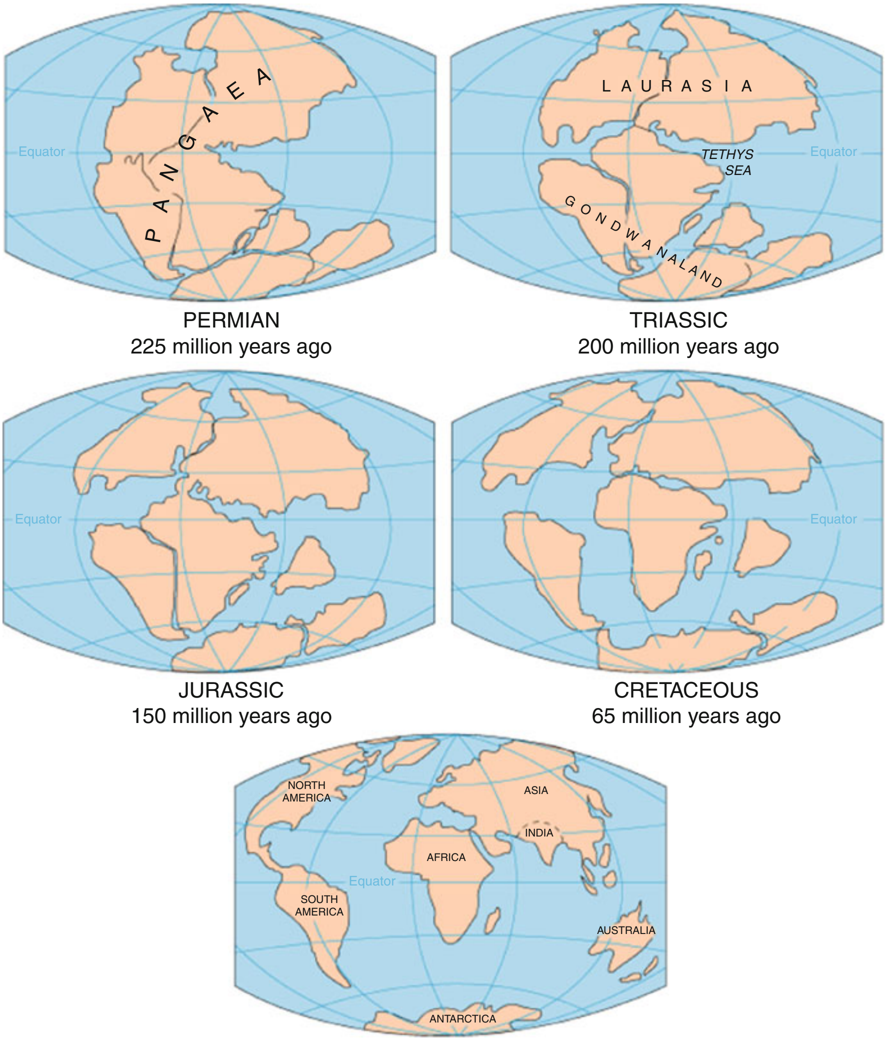

Fig. 16.7 Pangaea as it was in the Permian, how it broke apart, and how the continents are today (USGS, Public Domain)

Hawaii, and the Mid-Ocean ridges. In other words, earthquakes and volcanoes occur at the boundaries of plates and above hot spots (as in Hawaii).

The illustrations below in Fig. 16.7 show Pangaea as it was during the Permian and then as it has broken up through geologic Periods (Triassic, Jurassic, Cretaceous) and the continents have drifted to their current locations.

In geologic history, there have been a number of other supercontinents in addition to Pangaea; among them are the following with their years of existence:

- Gondwana (300–30 million years ago)
- Rodinia (1.1 billion–750 million years ago)

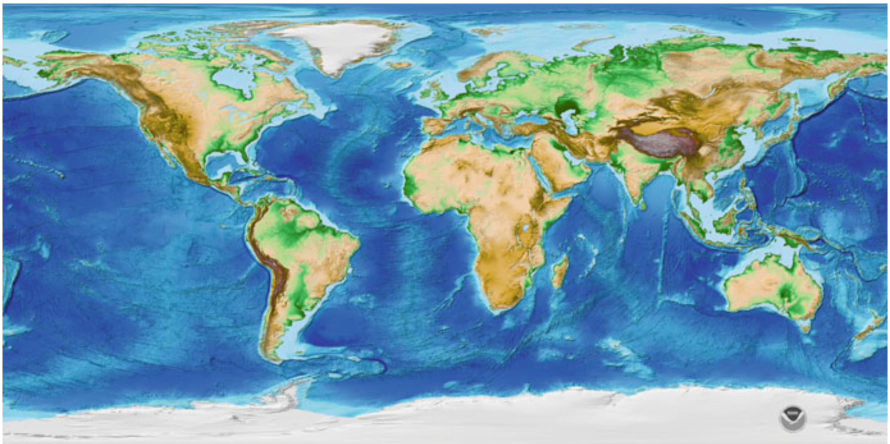

Fig. 16.8 Continental shelf areas of the world depicted in *light blue* (From NOAA, Public Domain)

- Laurasia (300–60 million years ago)
- Pannotia (600–540 million years ago)

These supercontinents represent areas of land that lasted for millions of years and eventually broke apart into various continents. The configuration of these land masses greatly affected Earth's climates of the past and most were centered along the equator at times (Fig. 16.7).

Geologically, continental areas consist of rocks that are high in silica and aluminum called sialic rocks (sial) and are represented by granite and rhyolite, whereas ocean basins are made up of rocks consisting of silica and magnesium or simatic rocks (sima) represented by basalt and gabbro. Other terms for continents and ocean basin rocks are acid and basic, respectively, although the terms do not refer to liquids called by the same names.

The largest continental shelf on Earth is the Siberian Shelf in the Arctic Ocean which stretches to 1,500 km (930 miles) in width. This continental shelf contains abundant reserves of carbon (methane) in the form of methane clathrates, as we've seen in a previous chapter (Chap. 15).

Continents with a great deal of relief (high standing mountain ranges, low valleys) usually have severe climatic conditions characterized by strong winds and diverse rainfall patterns. These types of climates are called continental climates. Some near coasts are modified by ocean currents.

16.5 Continental Mountain Ranges

Major mountain ranges of the continents are areas that tell scientists a great deal about how the Earth is made and are studied in order to unravel Earth's history. Maps showing major mountains can be found in a variety of sources including

Wikipedia and the many atlases and other resources available in online websites (e.g., wikipedia.org).

In the list below, no attempt was made to include all mountain ranges of the world. Major mountain ranges that can be found on most maps of the world are the following:

- The Appalachian Mountains are mainly in the continental United States but extend into southeastern Canada. They range from Newfoundland, Canada in the northeast to central Alabama, U.S. in the southwestern part of the range. They include the Piedmont, Blue Ridge, Ridge and Valley, and the Appalachian Plateau. The birth of the Appalachians, some 480 million years ago, marks the first of several mountain building plate collisions that culminated in the construction of the supercontinent Pangaea with the Appalachians near the center of that supercontinent. Because North America and Africa were connected at this time, the Appalachians formed part of the same mountain chain as the Little Atlas in Morocco. This mountain range, known as the Central Pangean Mountains, extended into Scotland, from the North America/Europe collision. Pangaea was a supercontinent consisting of Gondwana in the south and Laurentia in the north. Climates in the Appalachian Mountains are varied from season to season and from north to south. The Appalachian climate is affected by two ocean currents. The Labrador currents bring cold water south from the Arctic and cause freezing during the winter months in northern parts of the region. The Gulf Stream brings warm water north from the Caribbean and along the coast of North America before it turns east, crossing the Atlantic Ocean toward Europe. The meeting of the Gulf Stream and the Labrador Current also provides a great breeding ground for fish by enhancing the growth of plankton. The northern part of the region has an Arctic Climate, with extremely long, cold, winters and short, cool summers in Labrador, Newfoundland, and Nova Scotia.
- The Rocky Mountains are in the western part of North America in the United States and Canada. They are usually divided into the Northern, Middle, and Southern Rocky Mountains. Their geographic range is from northernmost British Columbia to New Mexico and south to Texas.
- The Andes Mountains are in western South America and constitute the longest continental mountain range in the world. The Andes Mountains are about 7,000 km (4,300 miles) long, about 200 km (120 miles) to 700 km (430 miles) wide (widest between 18° south and 20° south latitude), and of an average height of about 4,000 m (13,000 ft). The Andes extend from north to south through seven South American countries: Venezuela, Colombia, Ecuador, Peru, Bolivia, Chile and Argentina. The mountain range started to be built as the supercontinent of Pangaea began to break up around 250–200 million years ago during the Triassic Period of Earth history. The South American plate began to move westward as the crust was being subducted beneath it and what are now the Andes Mountains were subjected to compressive forces that folded, faulted, and uplifted the rocks that make up the mountain range.

- Ural Mountains run approximately north-south in western Russia from the coast of the Arctic Ocean to the Ural River and northwestern Kazakhstan. The eastern side of the Urals marks the division between Europe and Asia. The Uralian orogeny (mountain-building episode) began about 250–300 million years ago. The areas west to the Ural Mountains are 1–2°C (2–4°F) warmer in winter than the eastern regions because the former are warmed by the Atlantic winds whereas the eastern slopes are chilled by the Siberian air masses. The average January temperatures increase in the western areas from −20°C (−4°F) in the Polar to −15°C (5°F) in the Southern Urals and the corresponding temperatures in July are 10°C (50°F) and 20°C (68°F). A normal winter usually has a high pressure system over Siberia causing a dry period east of the Urals.
- Himalayan Mountains are the world's highest and contain the world's highest peaks, including Mount Everest at 8,848 m (29,029 ft). Some of the world's major river systems arise in the Himalayas, such as the Indus River, and their combined drainage basin is home to some three billion people (almost half of Earth's population) in 18 countries, many of them depending on glacial meltwater from Himalayan glaciers for drinking water and agriculture. The Himalayas have profoundly shaped the cultures of South Asia; many Himalayan peaks are sacred in Hinduism, Buddhism and Sikhism. Geologically, the Himalayas originated by the impact of the Indian tectonic plate traveling northward at about 15 cm per year to impact the Eurasian continent, with first contact about 70 million years ago, and with movement continuing today in the Himalayans and the Tibetan Plateau.
- The Beartooth Range is located in Wyoming and Montana northwest of Yellowstone National Park. The Beartooth Mountains extend above the larger Beartooth Plateau, the largest true high elevation plateau in the United States. The range is made of largely Precambrian granite and metamorphic rocks.
- The Alpine Mountain Range (the Alps) is one of the great mountain range systems of Europe, stretching from Austria and Slovenia in the east through Italy, Switzerland, Liechtenstein, Germany, France and Monaco in the west. It is the result of the African Plate travelling northward and impacting the Eurasian Plate.
- Pacific Coastal Ranges lie near the Pacific Ocean along the west coast of North America from Alaska to Baja California. The Coast Ranges are separated from the higher mountains of the Cascade Range and the Sierra Nevada to the east by broad depressions such as the Puget Sound Lowland in Washington, the Willamette Valley in Oregon, and the Central Valley in California. The Klamath Mountains of northern California and the Transverse Ranges of southern California serve as links to the eastern ranges. On the west the coastal plain is narrow, and deep water occurs within 25 miles (40 km) of the coast. The average elevation of the Coast Ranges is about 1,000 m (3,300 ft).
- The Ouachita Mountains stretch from west central Arkansas to southeastern Oklahoma in the U.S. and were originally part of the Appalachian chain of mountains. The rocks comprising them are the same as the folded and faulted Appalachians. The Ouachita Mountains were formed by the South American

Plate moving northward impinging on the North American Plate about 300 million years ago. The climate is mild and humid throughout.

- The Apennine Mountains consist of a series of mountains, 200 km (750 miles) northwest to southeast along the length of the Italian peninsula. The western slope contains most of the cities of Italy. The southern end of the peninsula has a semi-arid climate. The Apennines began about 20 million years ago and are the result of both compressive forces in the east and extensional forces in the west.
- The Atlas Mountains lie in a northwestern stretch of Africa extending about 2,500 km (1,600 miles) through Morocco, Algeria, and Tunisia. They separate the Atlantic and Mediterranean from the Sahara Desert. The mountains belong to the Saharan climate zone. They began to form, about 300 million years ago, when North America, Eurasia, and Africa were joined throughout much of the Paleozoic.
- The Caucasus is a mountain system in Eurasia between the Black Sea and the Caspian Sea that many consider to be the dividing line between Europe and Asia. The climate varies with altitude and latitude. The higher portions of the Caucasus are much colder than the lower portions with a difference of 21°F between the two. The Caucasus Mountains formed largely as the result of a tectonic plate collision between the Arabian plate moving northward with respect to the Eurasian plate.
- The Hindu Kush Mountains are an 800 km (500 mile) mountain range that stretches between central Afghanistan and northern Pakistan and are part of the Himalayan chain. The Hindu Kush, running northeast to southwest across the country of Afghanistan, divides it into three major regions: (1) the Central Highlands, which form part of the Himalayas and account for roughly two thirds of the country's area; (2) the Southwestern Plateau, which accounts for one-fourth of the land; and (3) the smaller Northern Plains area, which contains the country's most fertile soil.
- Owen Stanley Range is the southeastern part of the central mountain chain in Papua New Guinea, which is part of Melanesia. Papua New Guinea lies north of Australia and is part of the Pacific Ring of Fire. Papua New Guinea is located at the junction of several tectonic plates.
- Haraz Mountains are in Yemen and are part of the Arabian Peninsula. They are also a part of the Sarawat Mountains that run parallel to the western coast of the Arabian Peninsula. The Sarawat start from the border of Jordan in the north to the Gulf of Aden in the south, running through Saudi Arabia and Yemen. They are geologically part of the Arabian shield and consist mainly of volcanic rocks.
- The Japanese Alps are the high standing mountains that split the Japanese island of Honshū. They consist of three mountain ranges in Japan.
- The Pamir Mountains consist of a mountain range in Central Asia formed by the junction of the Himalayas, Tian Shan, Karakoram, Kunlun, and Hindu Kush ranges. They are among the world's highest mountains and have been known as the "Roof of the World."
- The Zagros Mountains constitute the largest mountains in Iran and Iraq. They run along Iran's western border from northernmost Iran to the Strait of Hormuz and the Persian Gulf in the south. They have been formed by a collision of the Arabian Plate with the Eurasian Plate. Iran's main oilfields lie in the western central foothills of the Zagros mountain range.

- The Balkan Mountains run for 560 km from the Vrashka Chuka/Vrška Čuka Peak on the border between Bulgaria and eastern Serbia eastward through central Bulgaria to the Black Sea. The mountains are mainly in Bulgaria and are part of the great mountain chain with the Alps in the west and the Himalayas in the east.
- The Basque Mountains are located in the northern part of the Iberian Peninsula which includes Spain, Portugal, and Andorra as well as the British territory of Gibraltar. Geographically it is considered to be the eastern section of the larger Cantabrian Range. The range runs through the Basque area of Northern Spain.
- The Carpathian Mountains are a range of mountains forming an arc roughly 1,500 km (932 miles) long across Central and Eastern Europe, making them the second-longest mountain range in Europe (after the Scandinavian Mountains, 1,700 km (1,056 miles)). The Carpathians consist of a chain of mountain ranges that stretch in an arc from the Czech Republic (3%) in the northwest through Slovakia (17%), Poland (10%), Hungary (4%), and Ukraine (11%) to Romania (53%) in the east and to the Danube River between Romania and Serbia (2%) in the south. The highest range within the Carpathians is the Tatras, on the border of Poland and Slovakia, where the highest peaks exceed 2,600 m (8,530 ft).
- The Jura Mountains are located north of the Alps in France, Switzerland, and Germany. They are a folded and faulted mountain range sharing an evolutionary geologic history with the Alps.
- The *Massif Central* is an elevated region in central France and contains the largest concentrations of extinct volcanoes in the world. The Auvergne Volcanoes National Park is in the *Massif Central*. These volcanoes were visited by some of the early European geologists who were prominent in the basalt controversy that raged over the origin of this rock, one side arguing that its origin was as a precipitate from a universal ocean (from the biblical Noachian Flood) and the other side arguing for a volcanic origin. The volcanoes of the Auvergne settled the argument on the side of the volcanoes, as it is possible to trace basalt lava flows up to the volcanic vents from which they issued.
- The Pyrenees Mountains form the divide between France and Spain and the boundary runs along the crest of the mountains. The Pyrenees are older than the Alps and were formed when the plate on which the present-day Spain sits was pushed northward into present-day France causing the crust to squeeze the sediments and metamorphics making up today's Pyrenees Mountains. There is also granite in parts of the range. The mountains were beginning to form about 150 million years ago.
- The Scandinavian Mountains run through the Scandinavian Peninsula and are the longest mountain range in Europe stretching 1,700 km (1,056 miles) along the peninsula. The famous fjords of Norway are glacially carved from the former streams that entered the North Sea and the Norwegian Sea. The mountain system was originally connected to the mountains of Scotland and Ireland and the Appalachian Mountains of North America. These formed a continuous mountain range before the breakup of the supercontinent Pangaea.
- The Adirondack Mountains are located in the northeastern part of New York State in the U.S. They are sometimes included in the Appalachians but have greater similarity to the Laurentian Mountains of Canada. They consist of

metamorphic and igneous rocks and are part of the Grenville lobe of the Canadian Shield that covers most of eastern and northeastern Canada and all of Greenland. The rocks range in age from 1.0 billion to 880 million years in age.

- The Arctic Cordillera is a low-standing mountain range in the Canadian Arctic Archipelago that extends into part of northern Labrador and northern Quebec, Canada. It includes Ellesmere Island and Baffin Island, two of the better known islands of the archipelago.
- The Blue Ridge Mountains are a high-standing range of the Appalachians in the eastern part of the United States. The Blue Ridge Mountains contain the highest mountains in eastern North America south of Baffin Island and consists of metamorphosed lava flows (e.g., greenstone), gneisses, and limestones. The Blue Ridge extends into Pennsylvania as South Mountain. While South Mountain dwindles to mere hills between Gettysburg and Harrisburg, the band of ancient rocks that forms the core of the Blue Ridge continues northeast through the New Jersey and Hudson River highlands, eventually reaching The Berkshires of Massachusetts and the Green Mountains of Vermont. The Great Smokey Mountains are a part of the Blue Ridge in North Carolina and Tennessee.
- The Brooks Range runs from northern Alaska into the Yukon Territory of Canada and is considered part of the Rocky Mountains. The Brooks Range forms the northernmost drainage divide in North America, separating streams flowing into the Arctic Ocean from those flowing into the North Pacific.
- The Cascade Range is a major mountain range of western North America extending from British Columbia into northern California. The Cascades are part of the Pacific Ocean Ring of Fire and contain active volcanoes. Lassen Peak in California and Mt. St. Helens are two of the active volcanoes, the former erupting in 1914 and the latter in 1980. There have been minor eruptions later, the last in 2008.
- The Sierra Nevada is a mountain range in California and Nevada, USA. One of its main features is Yosemite National Park formed from glacial activity during the last ice age. The Sierra Nevada range made a formidable obstacle for the settlers migrating westward into California. The Sierra Nevada snowpack is the major water source for California.
- The Sierra Madre Oriental, Mexico is a mountain range in northeastern Mexico. Its uplift has caused changes in weather patterns through its length. It is drier than the surrounding areas. West of the range lies the Mexican Plateau.
- The Sierra Madre Occidental, Mexico is in western Mexico. A great deal of rainfall occurs in the mountain range and the land on either side is drier. The climate varies from north to south. There are two wet seasons including a summer monsoon and two dry seasons.
- The Transantarctic Mountains, Antarctica extend across the continent of Antarctica and most likely consist of several different mountain ranges. They divide the continent into east Antarctica and west Antarctica.
- The Southern Alps, New Zealand extend for much of the length of the island. They occur along a geological plate boundary and are part of the Pacific Ring of Fire. The highest peaks in the range have snow and ice all year. There are

numerous glaciers and glacial lakes throughout the range. Christchurch, New Zealand has been hit with major earthquakes in 2011 and 2012.

- The Laurentian Mountains of Canada are located in southern Quebec. They are an extension of the Adirondack Mountains in New York State, USA. They are part of the Glenville mountain- building episode of Precambrian age, 1.1 billion years old.

16.6 Islands

There are two main types of natural islands: continental islands and oceanic islands. The continental islands are made of sialic material like granite and oceanic islands are made of simatic material like basalt. There are also man-made islands usually of sand and clay that have been constructed in areas where the economy has taken over from the niceties of nature.

Continental islands lie on the continental shelf and oceanic islands lie in the open ocean surrounded by oceanic crust. A special type forms an island arc which has a unique significance to plate tectonics. Island arcs are arcuate volcanic islands that mark subduction zones where one plate is being pulled down (subducted) and the adjacent plate is over-riding the one being pulled down.

An island is usually defined simply as land that is surrounded by water.

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