Major Concepts in Geology
(The science dealing with time)

THE EARTH IS A DYNAMIC BODY EVOLVING THROUGH TIME

The most fundamental principle of geology is that the earth is a dynamic body evolving through time.

The earth undergoes important reactions driven by various energy sources.

The idea that the earth is dynamic implies that it is supplied with sources of energy which can drive chemical reactions and physical reactions.

The earth is subjected both to:

a. **External supplies of energy and forces (from the Sun)**
b. **Internal supplies of energy (outflow of earth's internal heat)**

Hutton's doctrine 'Present is the key to the past' was expounded and illustrated by Charles Lyell as the 'Principles of uniformitarianism'

- **Hydrologic cycle**
- **Rock cycle**

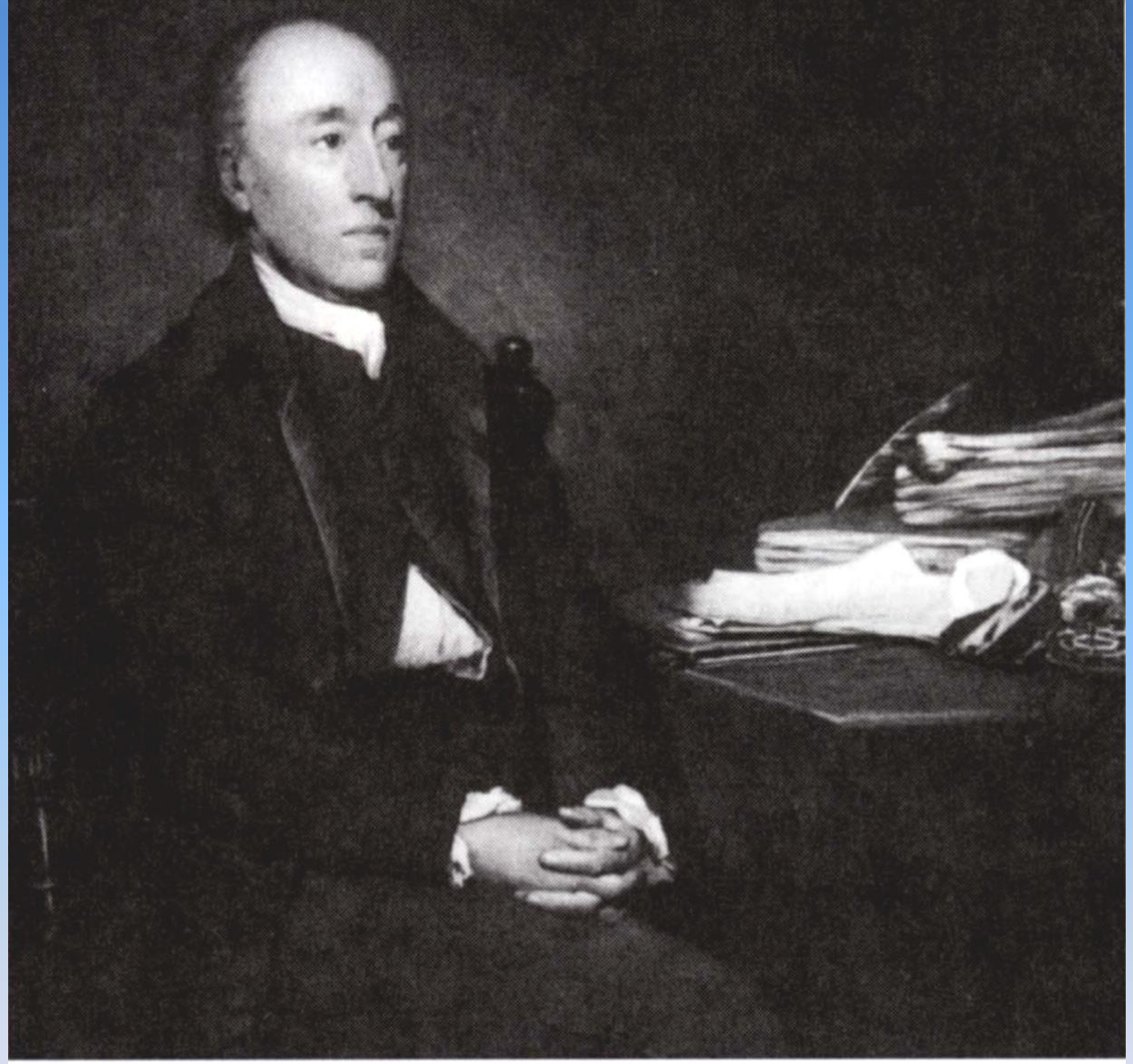


Figure 1.2 James Hutton, the eighteenth-century Scottish geologist who is often called the "father of modern geology." (Photo courtesy of the British Museum)

Figure 1.3 Charles Lyell. Lyell's book, *Principles of Geology*, did much to advance modern geology. (Courtesy of the Institute of Geological Sciences, London)

Hydrologic Cycle

The water cycle (also known as the hydrologic cycle or the H2O cycle) defines the continuous movement and storage of water through Earth (on, above and below the surface).

Water on Earth is constantly moving and changing states.

Reservoirs of water

A reservoir stores water for a period of time. Not all reservoirs hold water for the same amount of time. Glaciers, for example, can keep water trapped as ice for thousands of years.

The atmosphere, on the other hand, keeps water for an average of nine days before it releases it down as rain or snow.

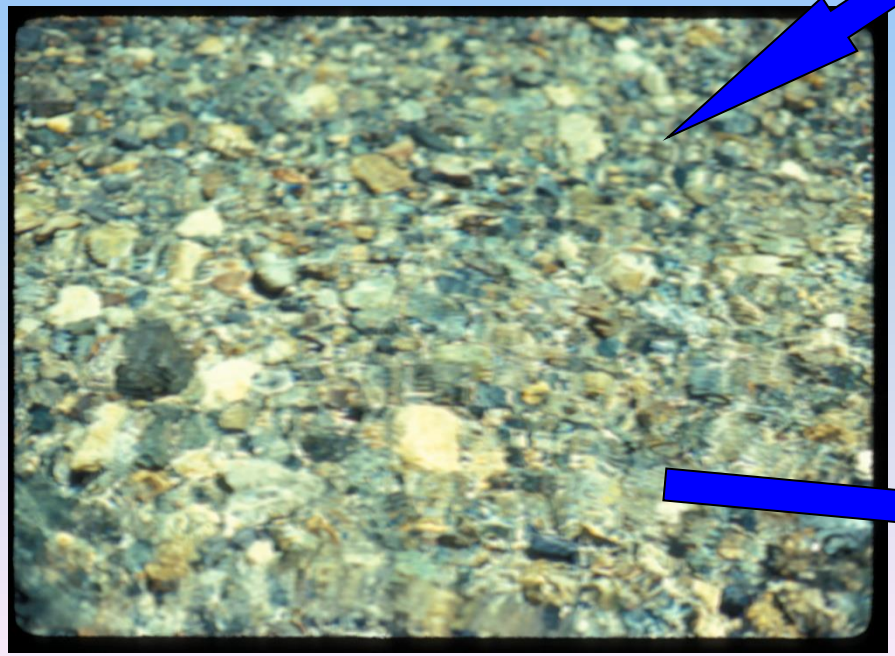
Below is a list of the different reservoirs that water can be stored:

1. **Atmosphere**
2. **Oceans**
3. **Lakes**
4. **Rivers**
5. **Soils**
6. **Glaciers**
7. **Snow fields**

Location	surface area		water volume		percent of total
	sq mi	sq km	cu mi	cu km	
SURFACE WATER					
fresh-water lakes	330,000	860,000	30,000	125,000	0.009
saline lakes and inland seas	270,000	700,000	25,000	104,000	0.008
average in stream channels	—	—	300	1,250	0.0001
SUBSURFACE WATER	50,000,000	130,000,000			
soil moisture and intermediate zone (vadose) water			16,000	67,000	0.005
ground water within 0.5 mi (0.8 km) depth			1,000,000	4,170,000	0.31
ground water, deep-lying			1,000,000	4,170,000	0.31
total liquid water in land areas			2,070,000	8,637,000	0.635
GLACIERS	6,900,000	18,000,000	7,000,000	29,200,000	2.15
ATMOSPHERE	197,000,000	510,000,000	3,100	13,000	0.001
WORLD OCEAN	139,500,000	360,000,000	317,000,000	1,322,000,000	97.2
Totals (rounded)			326,000,000	1,360,000,000	100

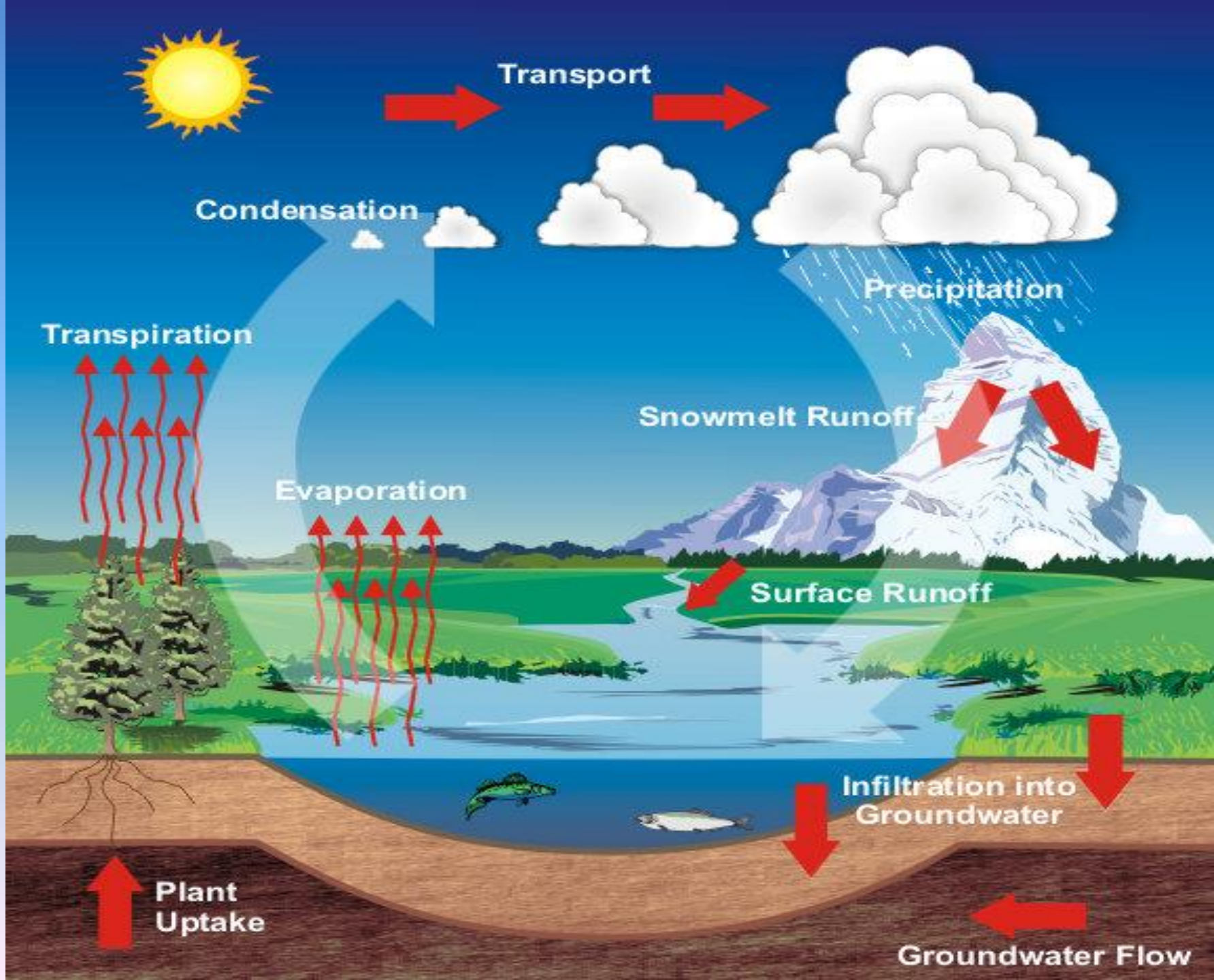
Figure by MIT OCW

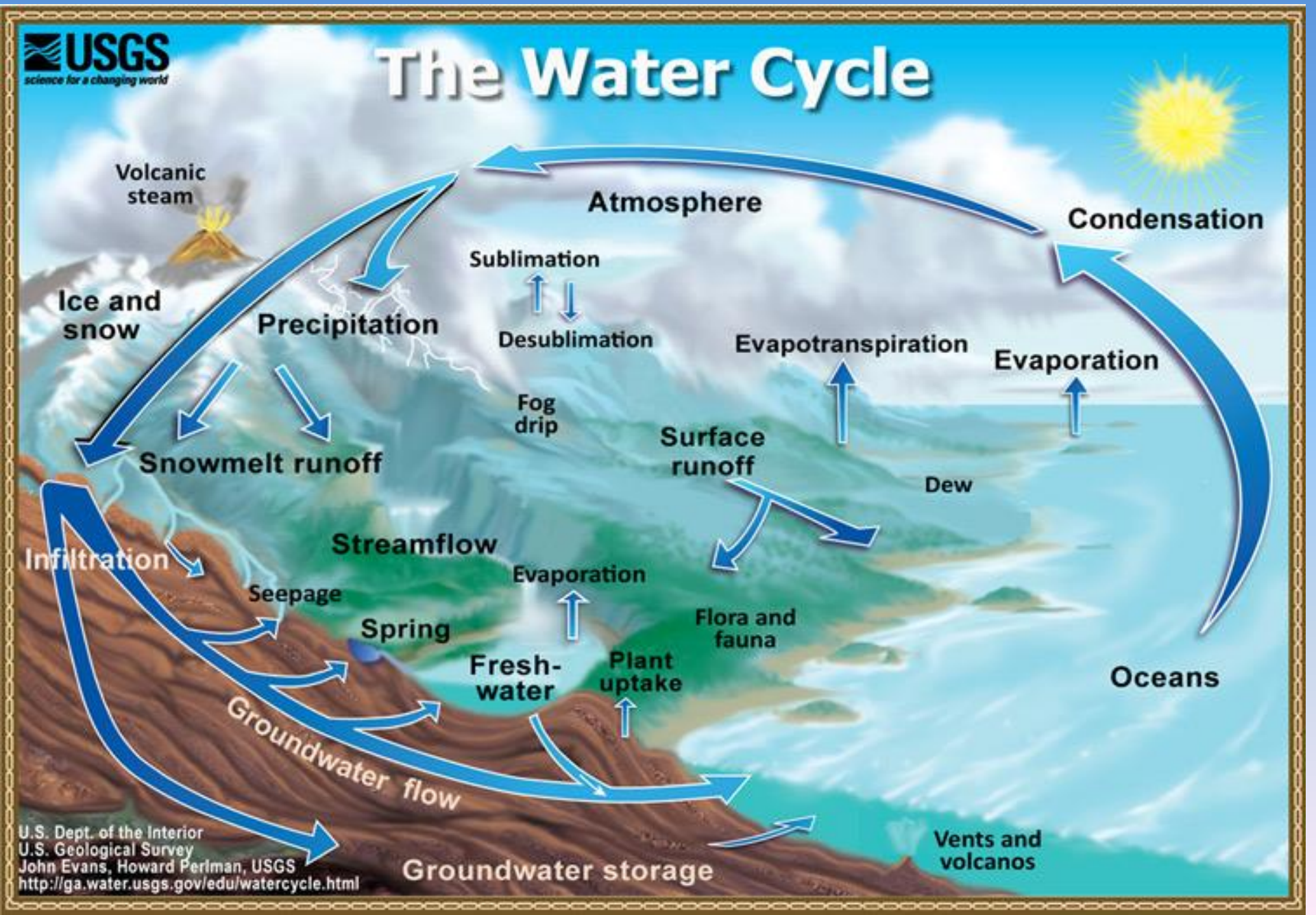
Table 12-1. An accounting of where the Earth's water resides. (From Strahler, 1975.)

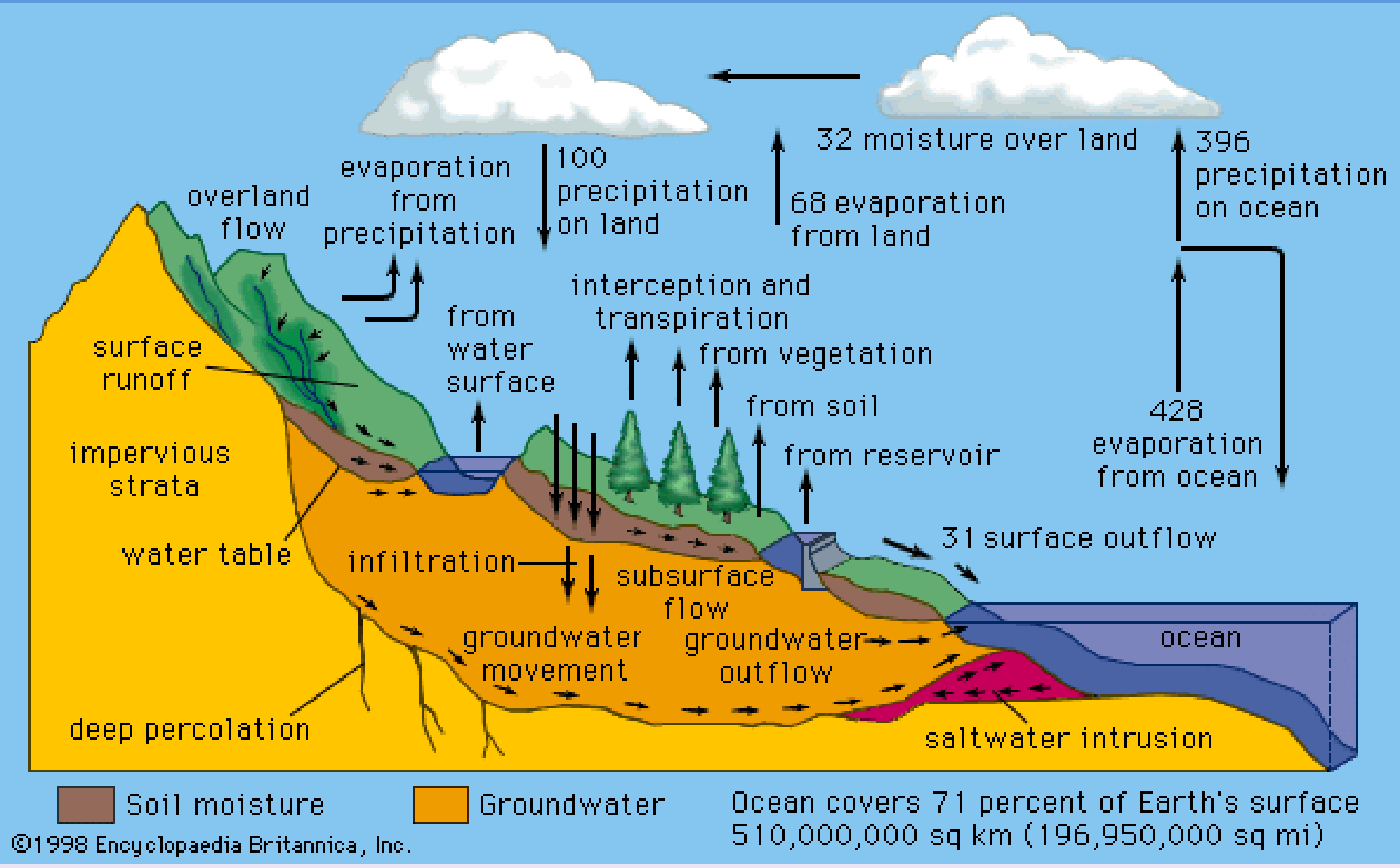


A HYDROLOGIC CYCLE

Hydrologic cycle




USGS
science for a changing world
The Water Cycle
Volcanic steam
Atmosphere
Condensation
Sublimation
Desublimation
Ice and snow
Precipitation
Evapotranspiration
Evaporation
Fog drip
Surface runoff
Snowmelt runoff
Dew
Streamflow
Infiltration
Evaporation
Seepage
Spring
Flora and fauna
Fresh-water
Plant uptake
Oceans
Groundwater flow
Vents and volcanos
Groundwater storage
U.S. Dept. of the Interior
U.S. Geological Survey
John Evans, Howard Perlman, USGS
http://ga.water.usgs.gov/edu/watercycle.html



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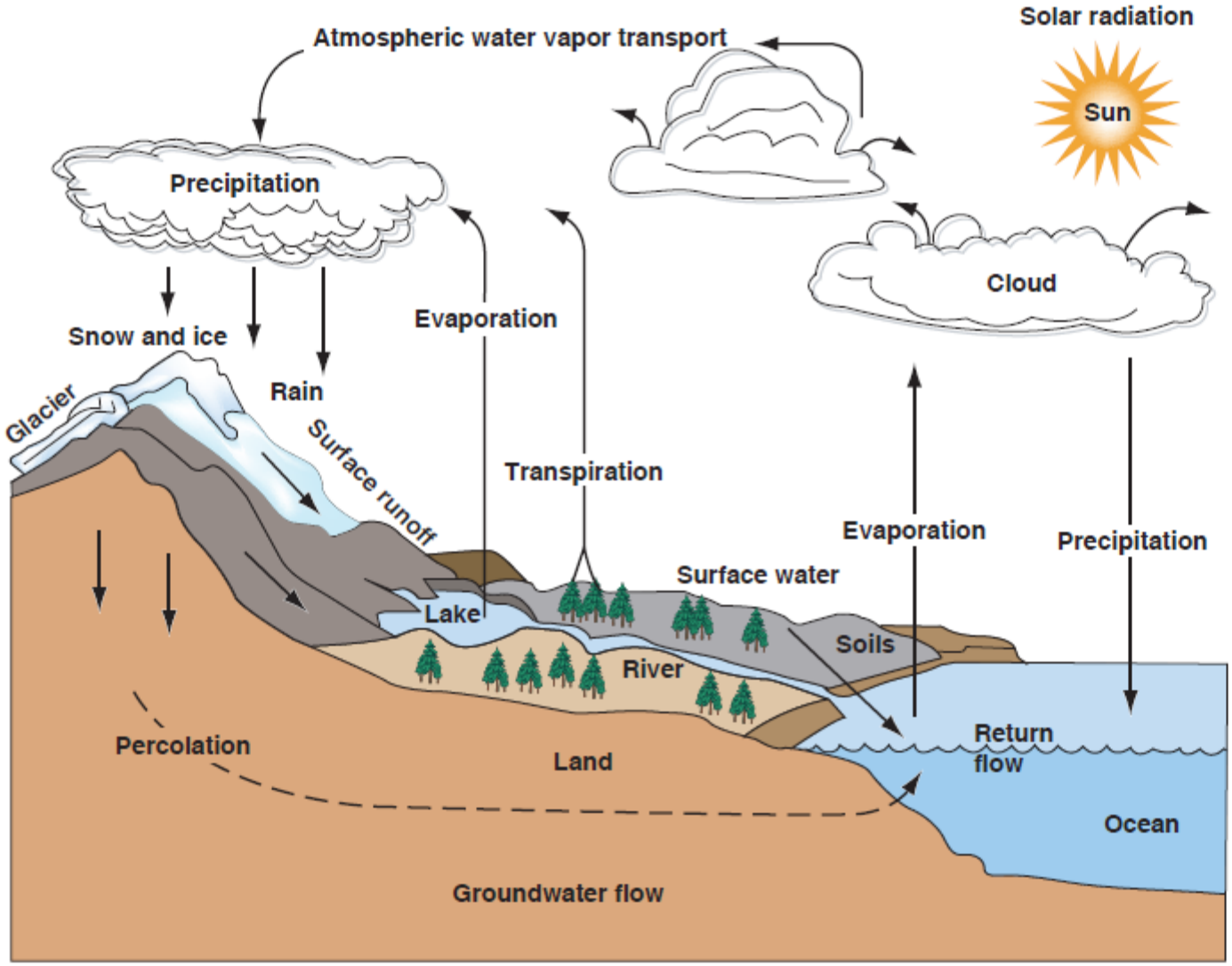


Figure by MIT OCW

Figure 12-1. The hydrologic cycle. (From Water, The Yearbook of Agriculture 1955.)

THREE GREAT GROUPS OF ROCKS

AND THE ROCK CYCLE

Geologic Cycle

THE GEOLOGIC CYCLE AND THE GEOLOGIC RECORD

JAMES HUTTON AND THE UNIFORMITARIAN PRINCIPLE

The concept of the geologic cycle developed in the late eighteenth and early nineteenth century, became the basis of one of geology's greatest, triumph (achievement), the proof of enormous age of the earth.

The idea that were put together into what became known as the geologic cycle represent one of the greatest intellectual achievements of all time.

They were the work of one man - James Hutton (1726-1797).

Hutton was a farmer who set about attempting to apply the latest scientific methods in agriculture to his farm in Scotland.

Fundamental to the interpretation of geological phenomena is a principle first proposed and abundantly illustrated by James Hutton.

Hutton (1785) attributed all geologic phenomena- mountain ranges such as the Alps, deep canyons and integrated river valleys system, the soil, the very rock themselves- to natural observable processes such as those seen in operation today.

"UNIFORMITARIAN PRINCIPLE"

He began to study the rocks and the surface features of the earth. About 1768 he left the farm and began to do geologic research up to the rest of the life.

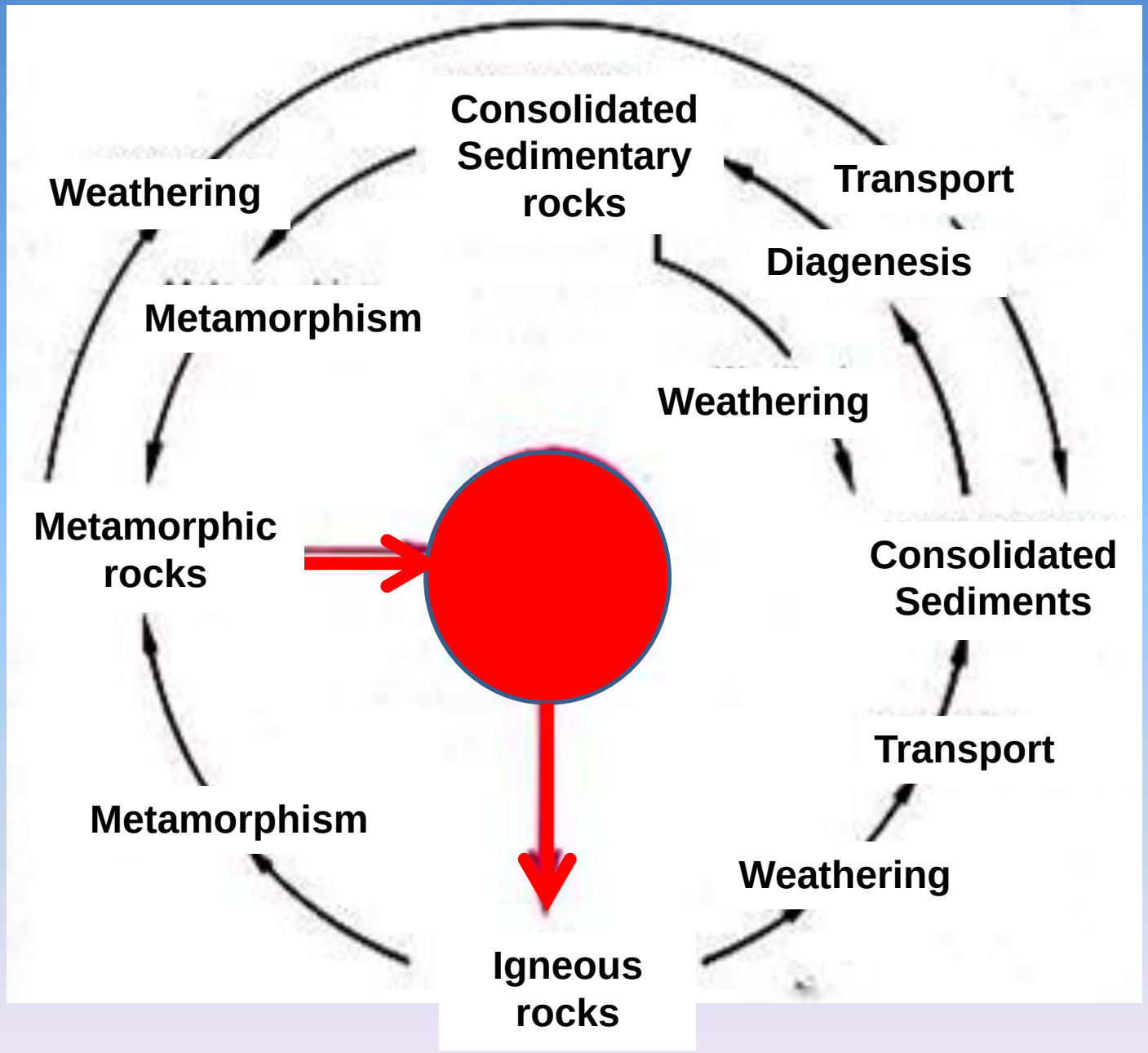
Hutton proposed a whole new way of looking at the world, which he named a "theory of the earth".

Hutton saw what was happening in the related activities we now know as the water cycle or hydrologic cycle:

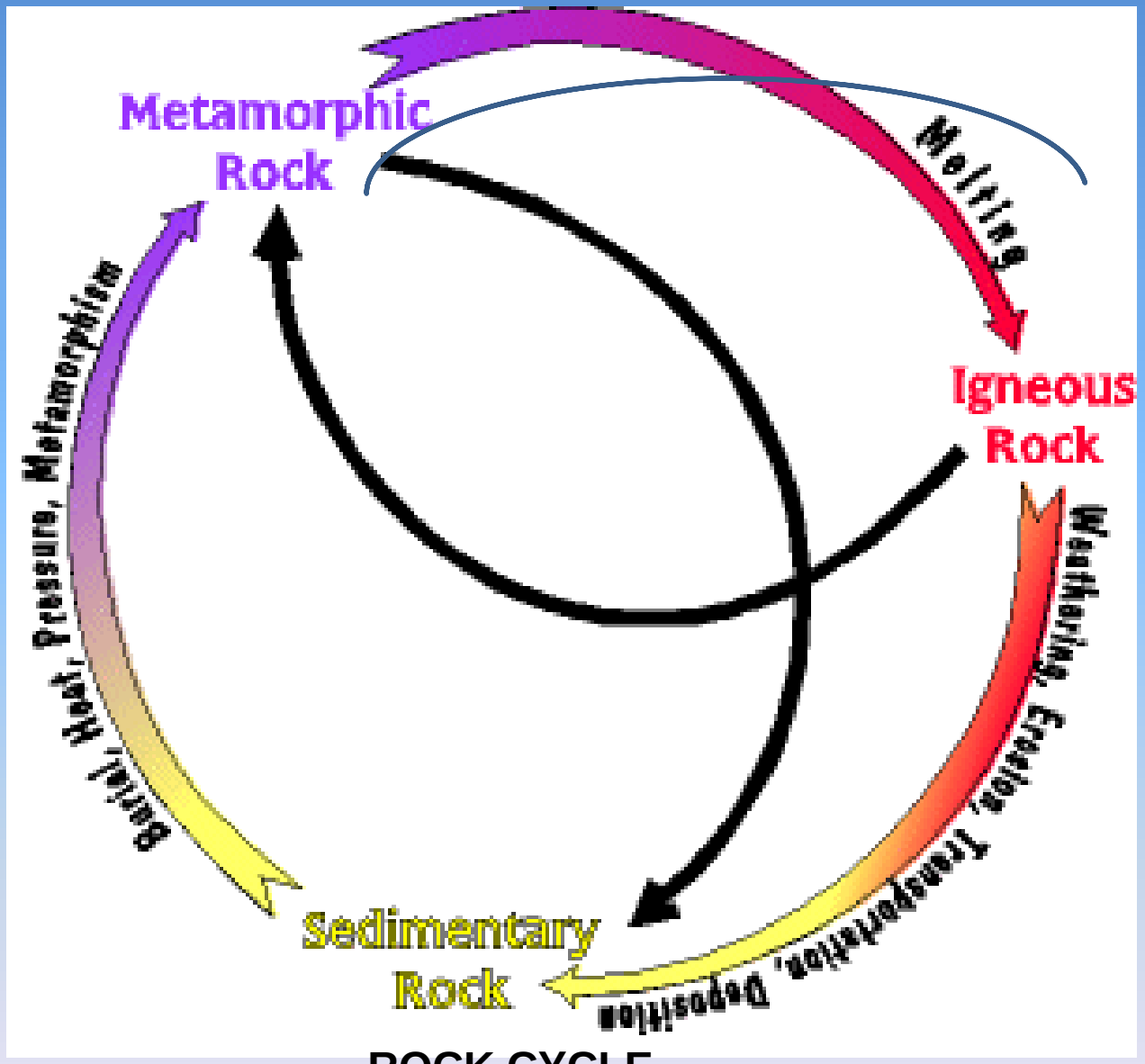
bed rock-regolith-sediment-strata or layer

What Hutton did was to point out that the geologic cycle operates and important subcycle that became known as rock cycle.

Geologic Cycle

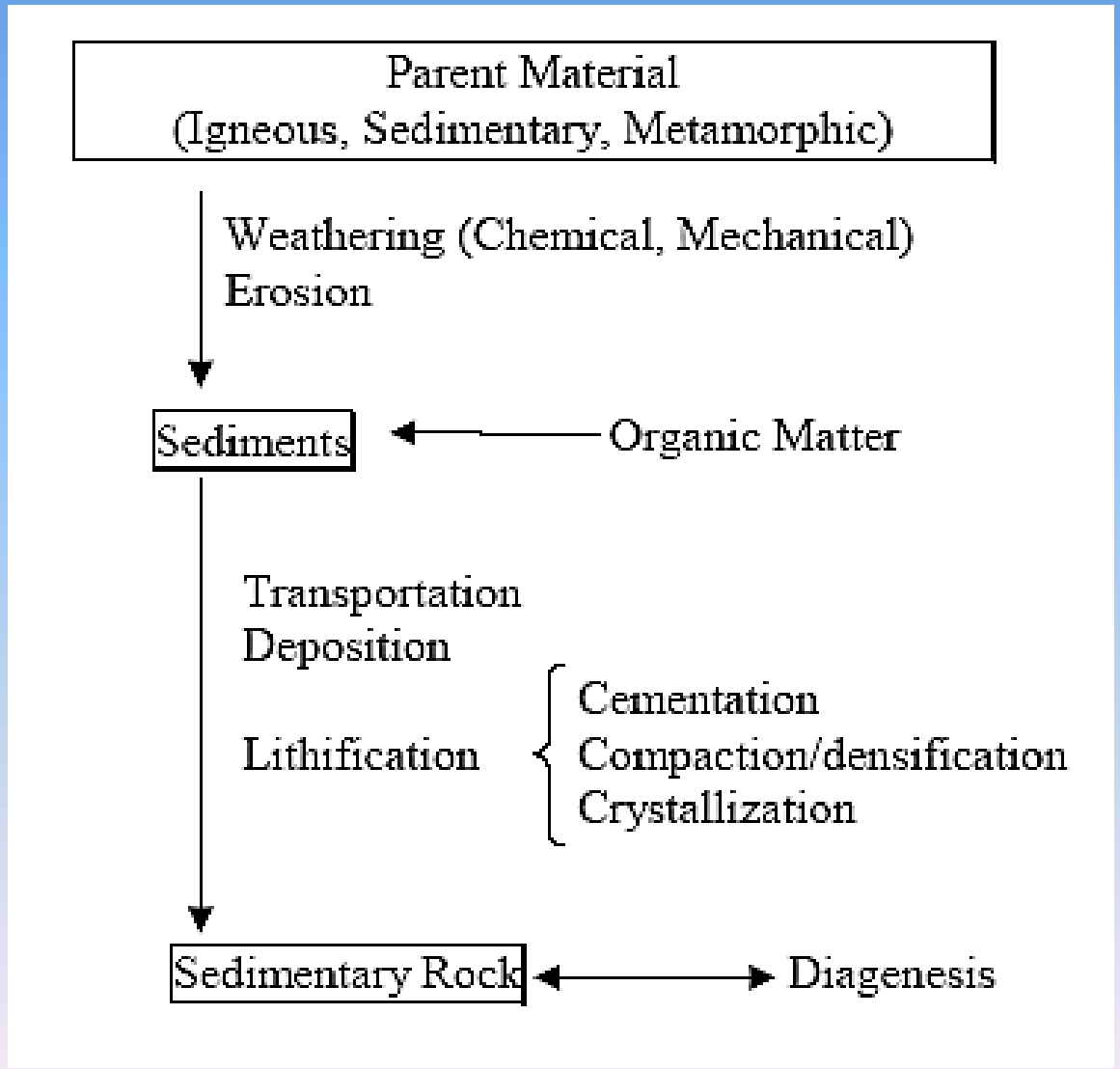


Rocks are related to each other through the ROCK CYCLE & the TECTONIC ROCK CYCLE


Metamorphic Rock
Melting
Igneous Rock
Weathering, Erosion, Transportation, Deposition
Sedimentary Rock
Burial, Heat, Pressure, Metamorphism

ROCK CYCLE

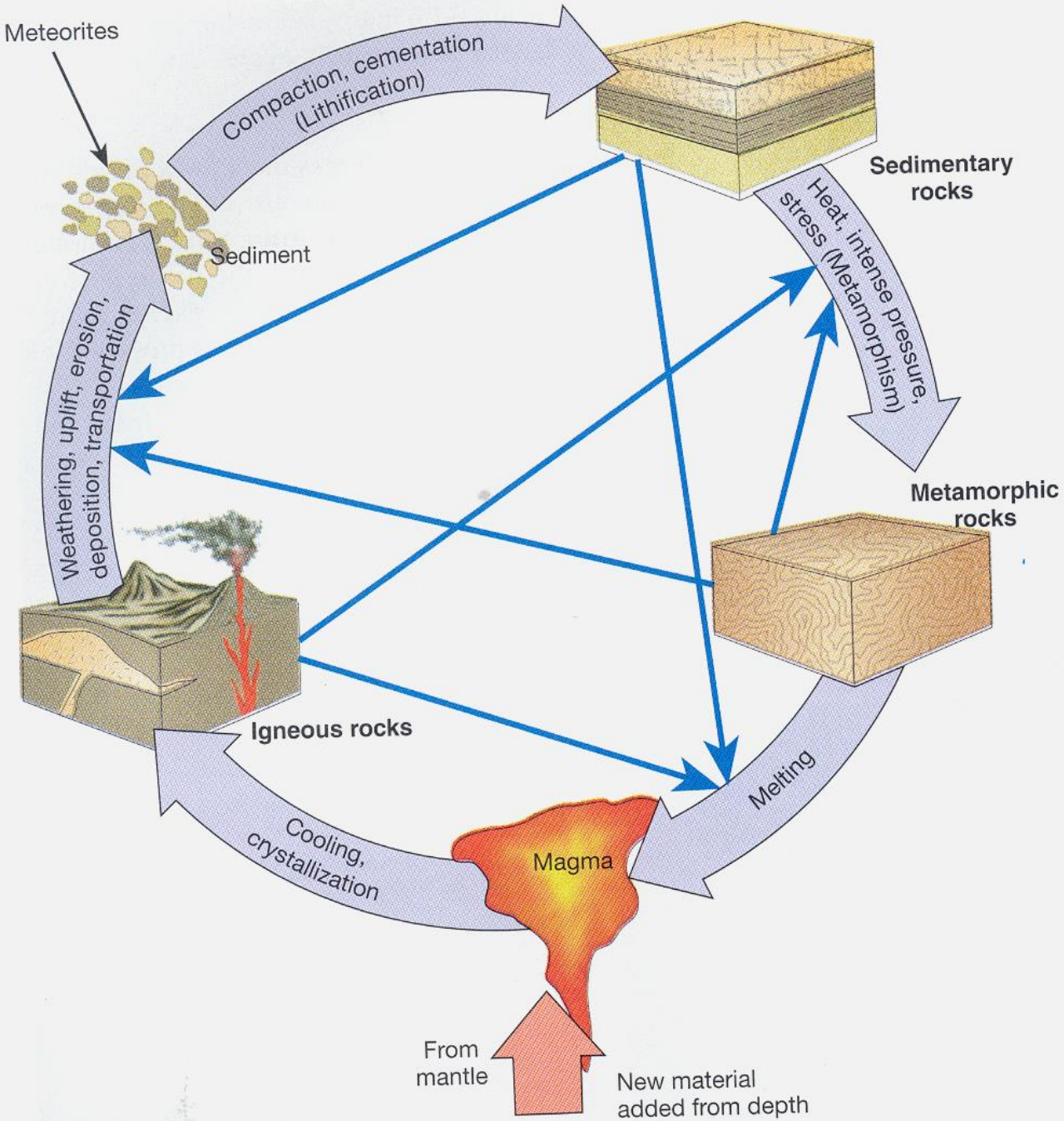
SEDIMENTARY ROCKS FORMATION

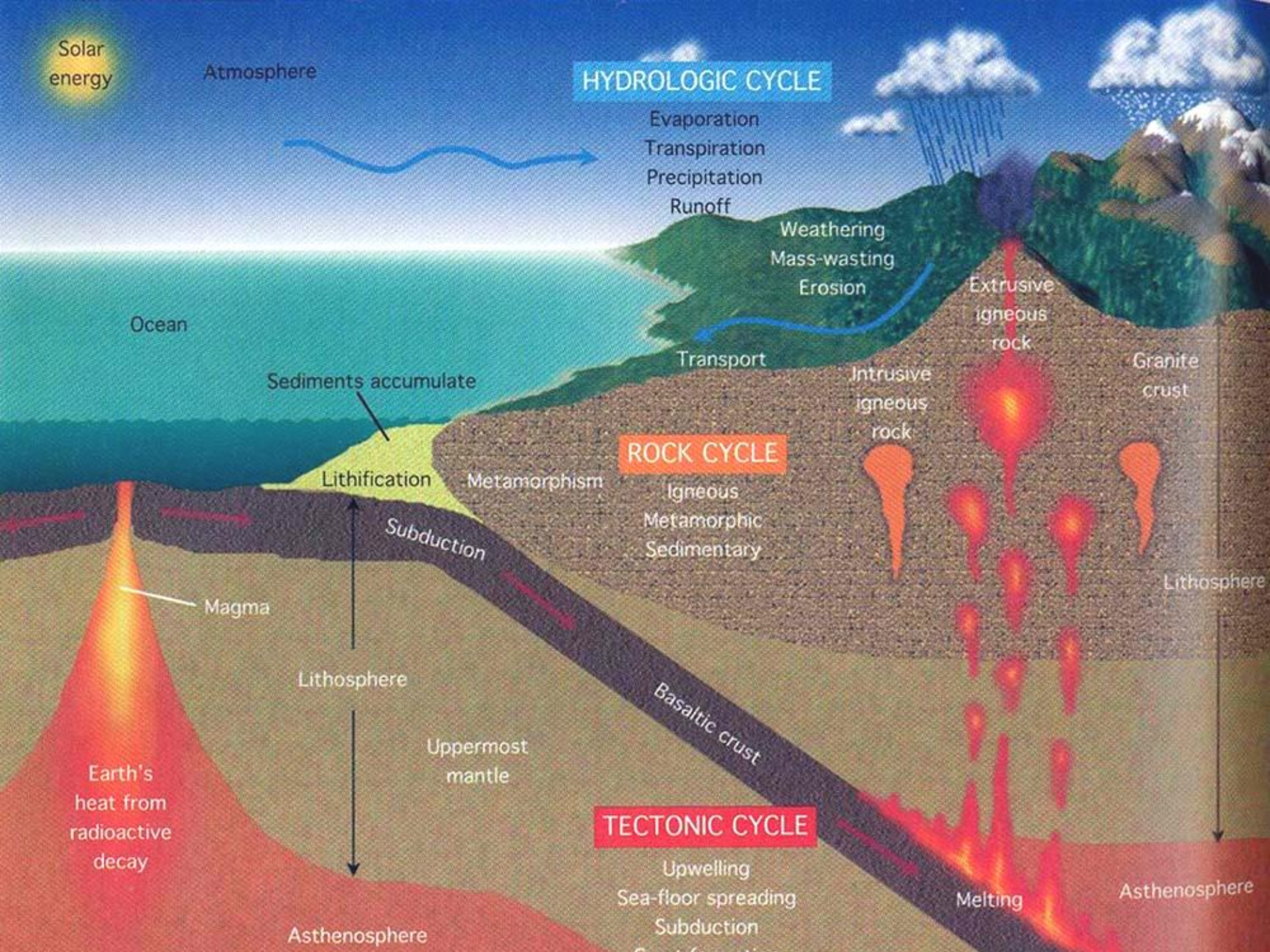


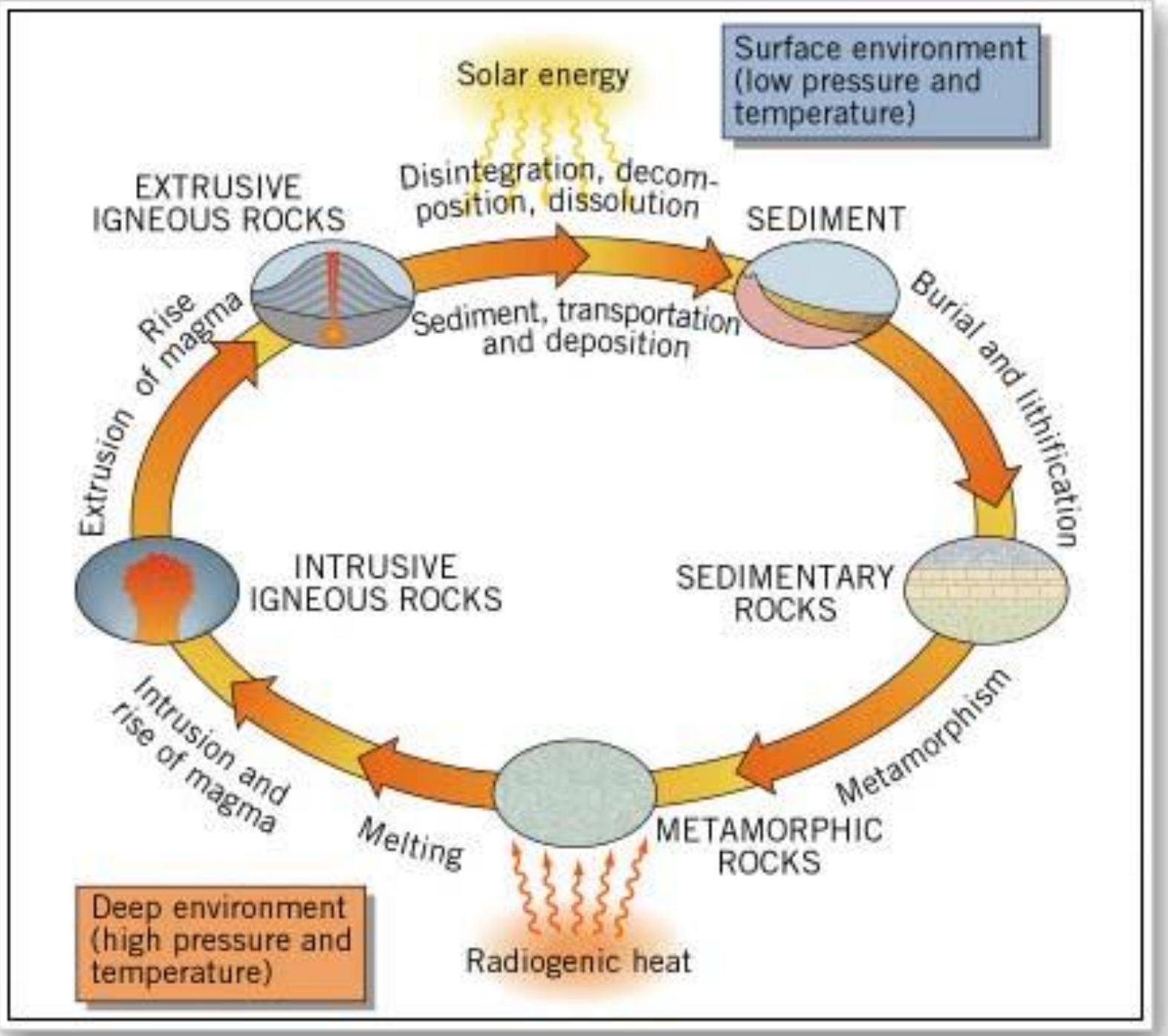
In many cases sediments experience various changes as a result of being buried. These changes take place because of the:

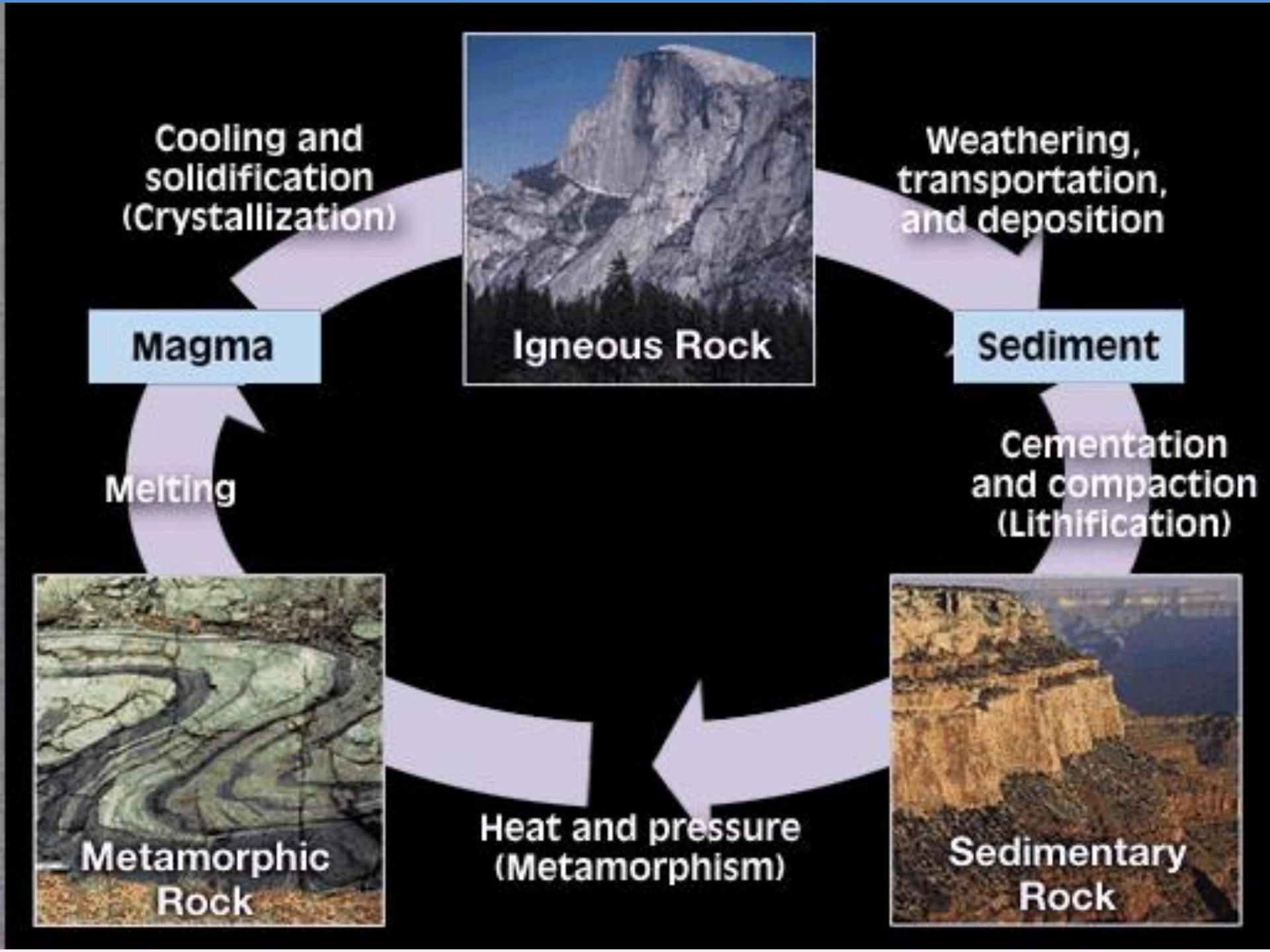
1. **Higher Temperature**
2. **Greater Pressure**
3. **Chemically active fluids found beneath the surface**

The general name for all changes that deposited sediments experience is called diagenesis.


Meteorites
Compaction, cementation (Lithification)
Sedimentary rocks
Heat, intense pressure, stress (Metamorphism)
Metamorphic rocks
Sediment
Weathering, uplift, erosion, deposition, transportation
Igneous rocks
Melting
Cooling, crystallization
Magma
From mantle
New material added from depth


Solar energy
Atmosphere
HYDROLOGIC CYCLE
Evaporation
Transpiration
Precipitation
Runoff
Weathering
Mass-wasting
Erosion
Ocean
Extrusive igneous rock
Granite crust
Transport
Intrusive igneous rock
Sediments accumulate
ROCK CYCLE
Igneous
Metamorphic
Sedimentary
Lithification
Metamorphism
Subduction
Lithosphere
Magma
Lithosphere
Basaltic crust
Uppermost mantle
Earth's heat from radioactive decay
TECTONIC CYCLE
Upwelling
Sea-floor spreading
Subduction
Melting
Asthenosphere
Asthenosphere


Surface environment (low pressure and temperature)
Solar energy
EXTRUSIVE IGNEOUS ROCKS
Disintegration, decomposition, dissolution
SEDIMENT
Rise of magma
Extrusion
Sediment, transportation and deposition
Burial and lithification
INTRUSIVE IGNEOUS ROCKS
SEDIMENTARY ROCKS
Intrusion and rise of magma
Melting
Metamorphism
METAMORPHIC ROCKS
Deep environment (high pressure and temperature)
Radiogenic heat


Cooling and solidification (Crystallization)
Igneous Rock
Weathering, transportation, and deposition
Magma
Sediment
Melting
Cementation and compaction (Lithification)
Metamorphic Rock
Heat and pressure (Metamorphism)
Sedimentary Rock

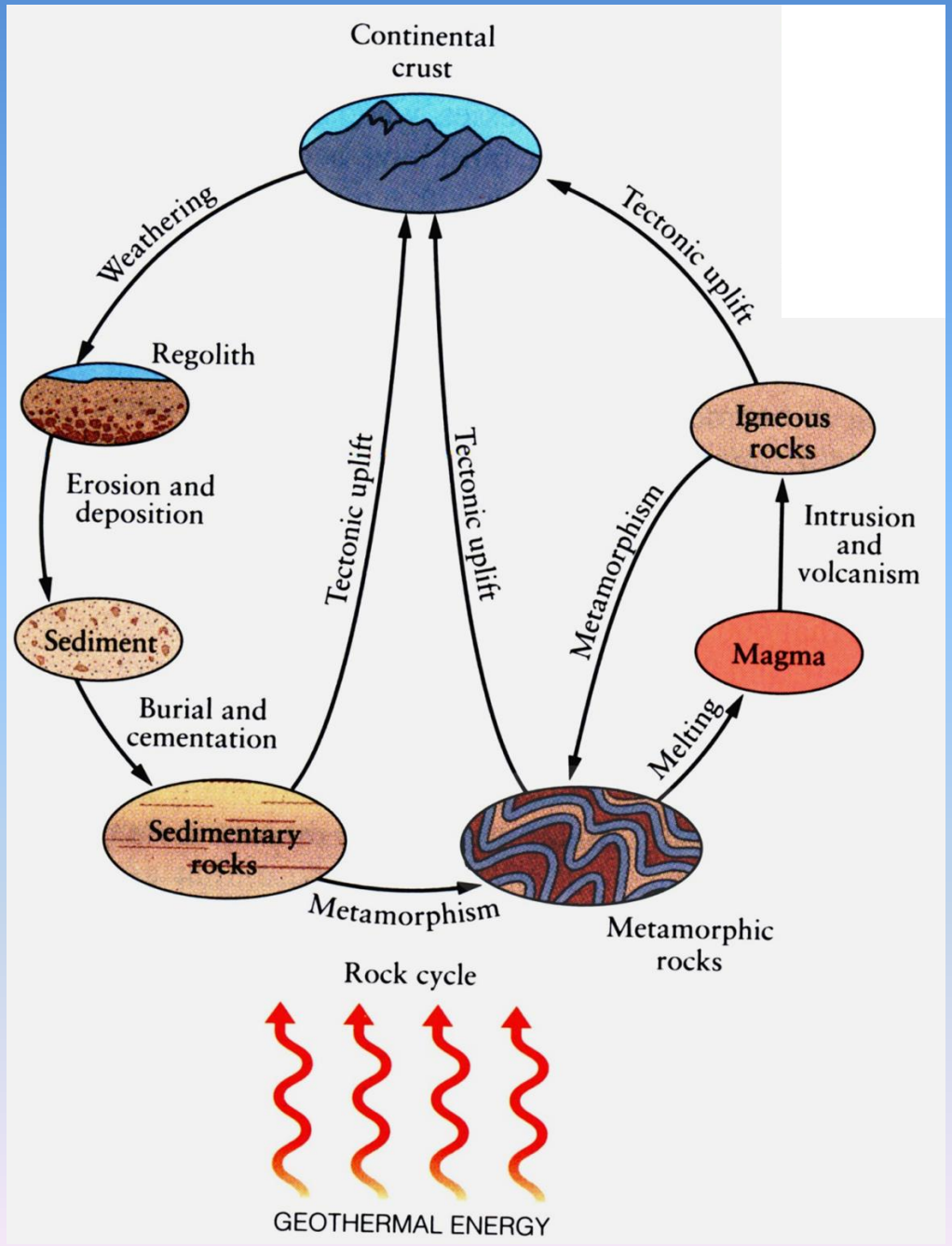
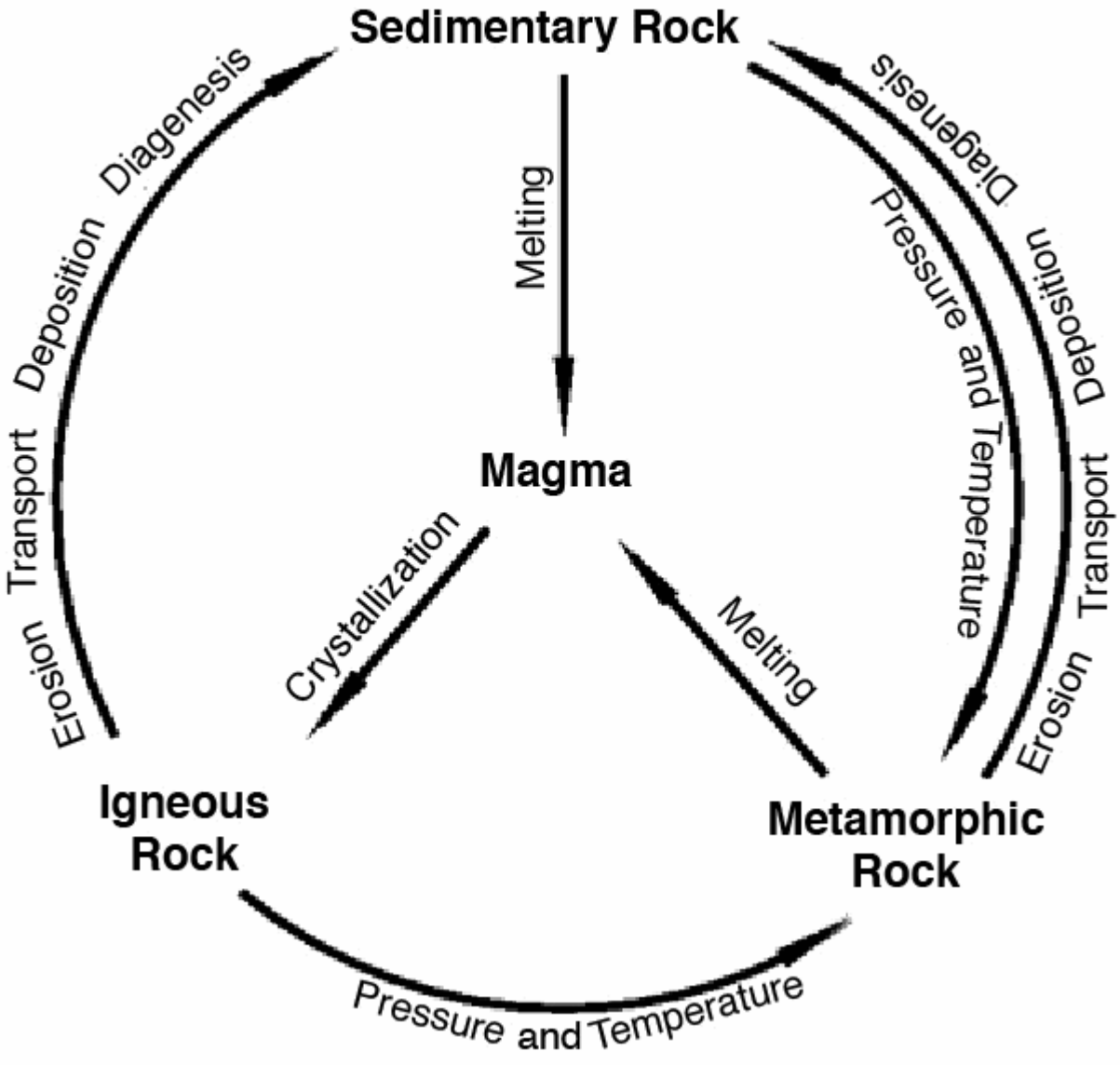
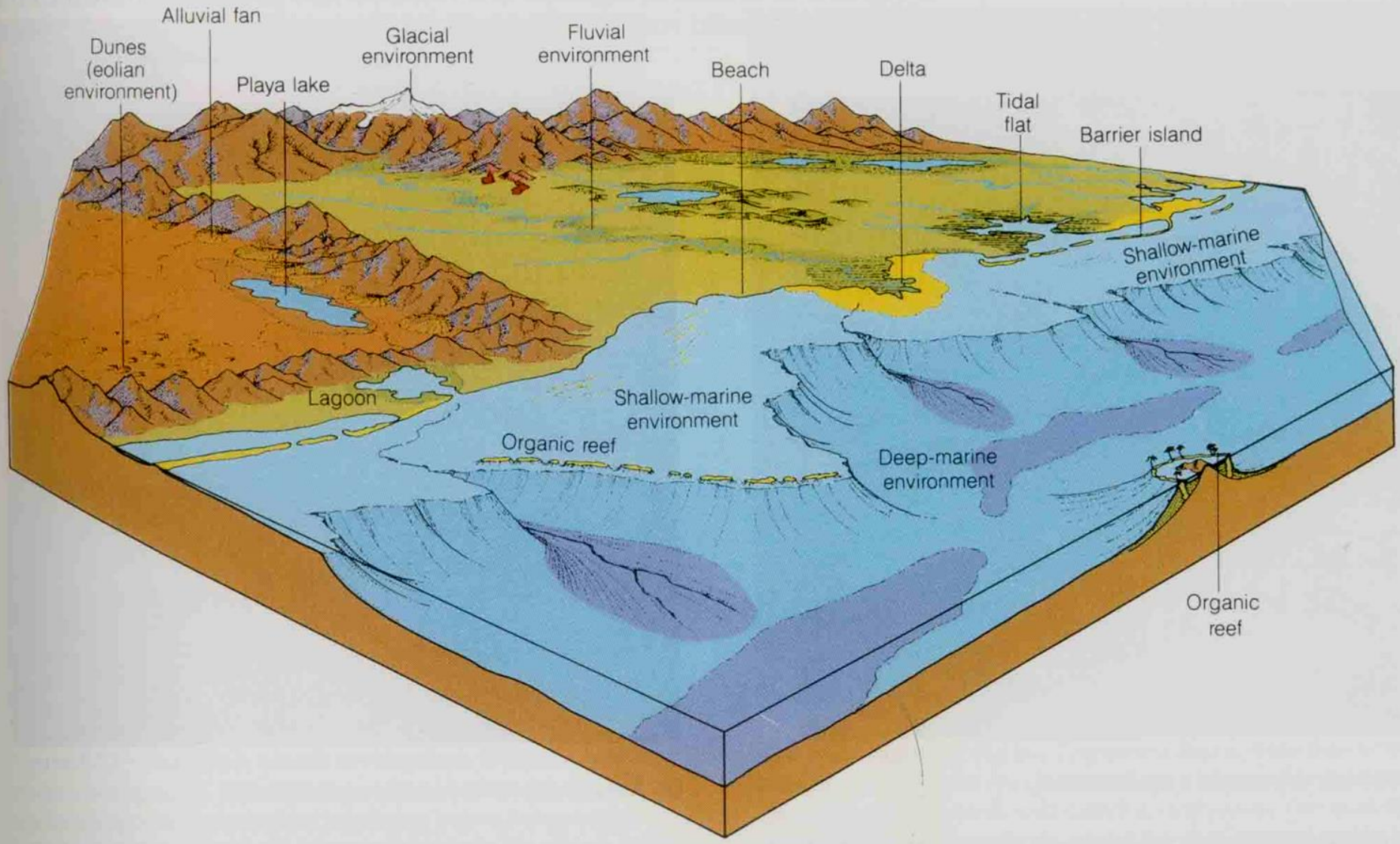


Fig. 2.19: The Rock Cycle. The rock cycle traces the processes whereby materials within and on top of the Earth's crust are weathered, deposited, metamorphosed, and even melted. Note that rocks don't necessarily follow the path that leads around the outside of the circle; they can follow any of the short circuits from one stage to another.

Rock Cycle


Sedimentary Rock
Melting
Magma
Crystallization
Melting
Igneous Rock
Metamorphic Rock
Pressure and Temperature
Erosion
Transport
Deposition
Diagenesis
Diagenesis
Deposition
Transport
Erosion
Pressure and Temperature

the **sedimentary environment**—that is, the physical, chemical, and biological conditions that exist at the place where the sediment is deposited.



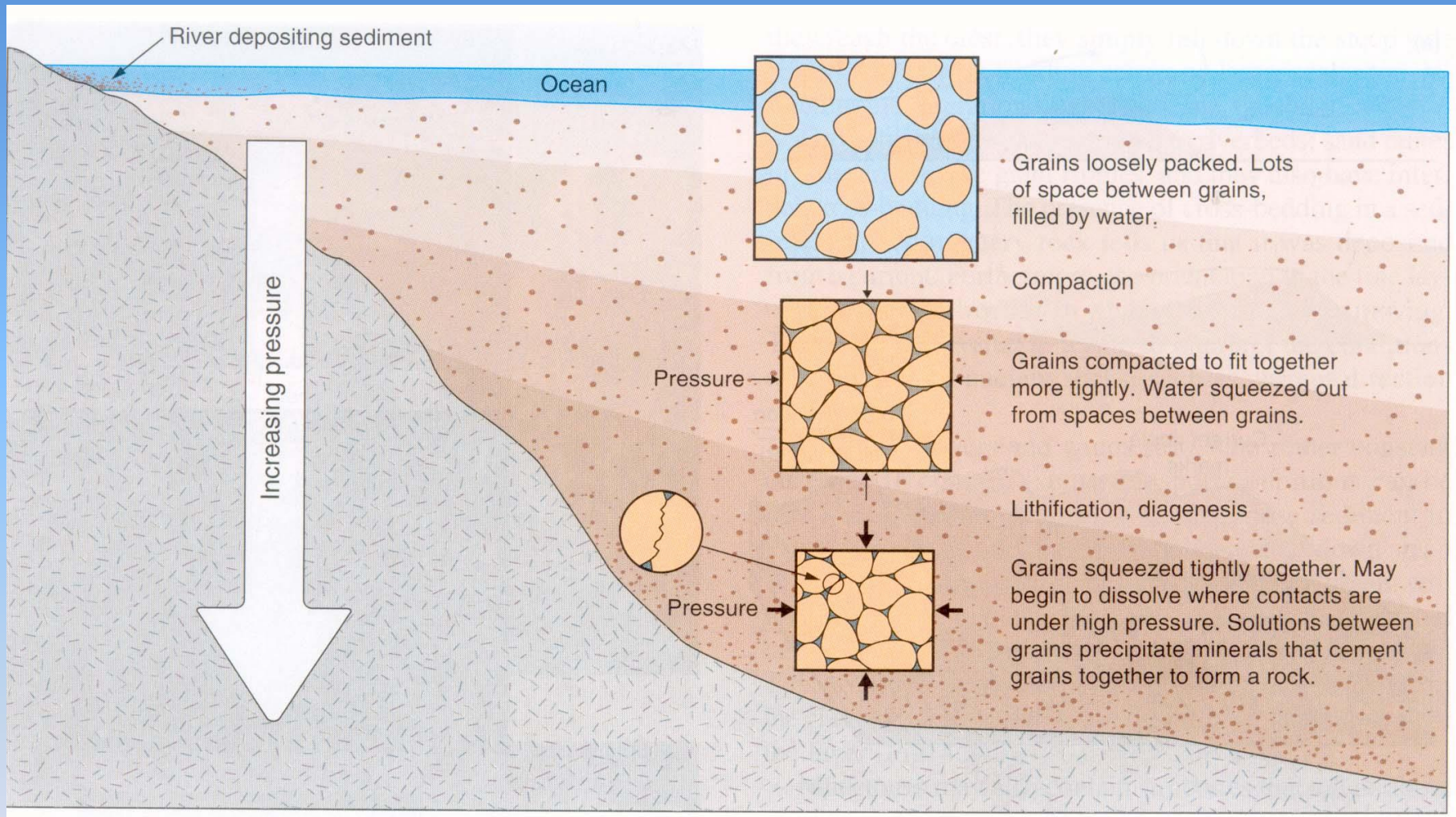


FIGURE 4.25 Schematic illustration of the process of compaction, lithification, and diagenesis that takes place with increasing depth in a thick pile of sediments in a sedimentary basin.

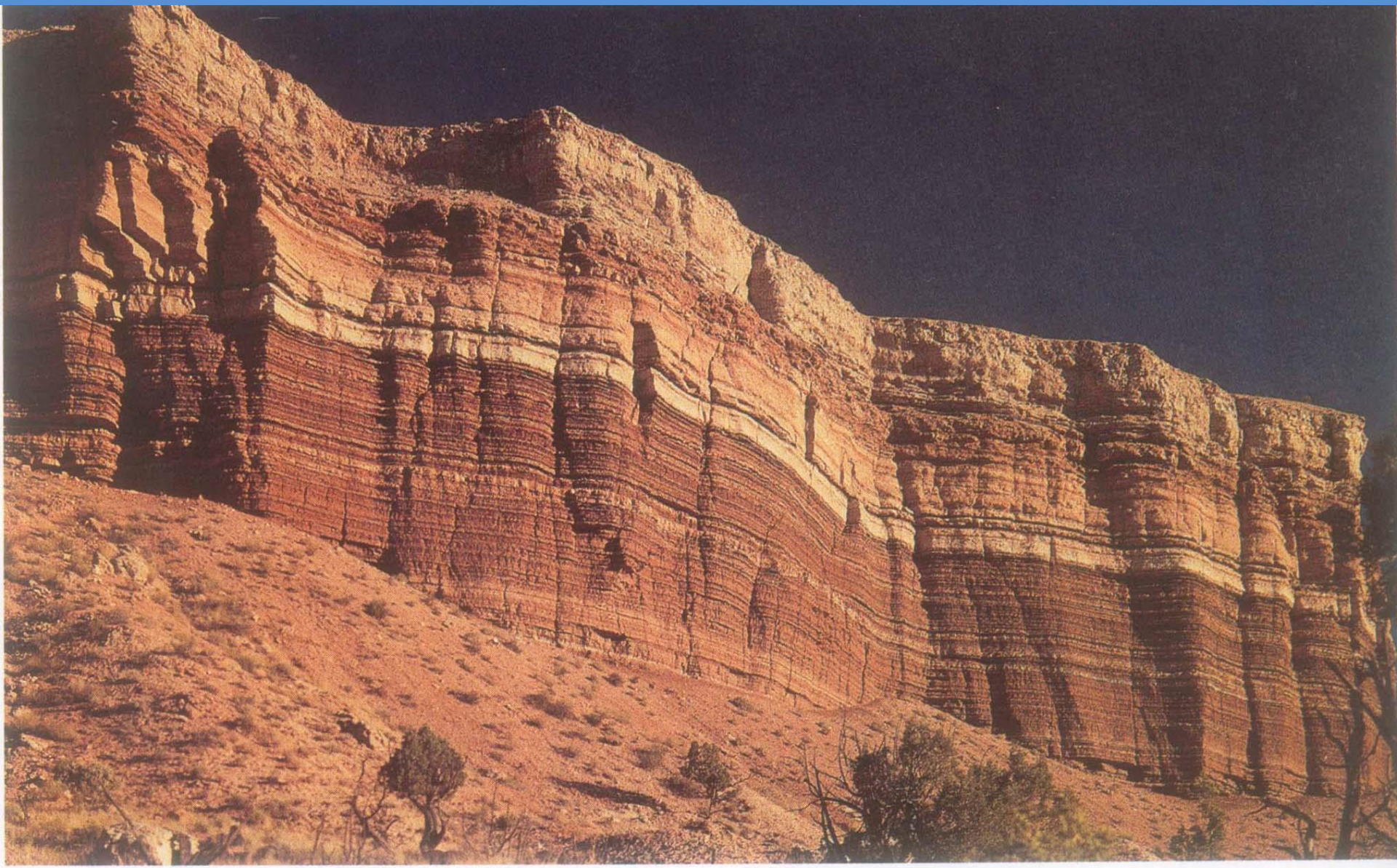


Figure 6.1 Layers of Sedimentary Rock: Bedding When you look at an outcrop of sedimentary rock, one of the first things you notice is layering, or bedding. Here, layered sedimentary rocks in Capital Reef National Park, Utah, have been exposed by erosion.

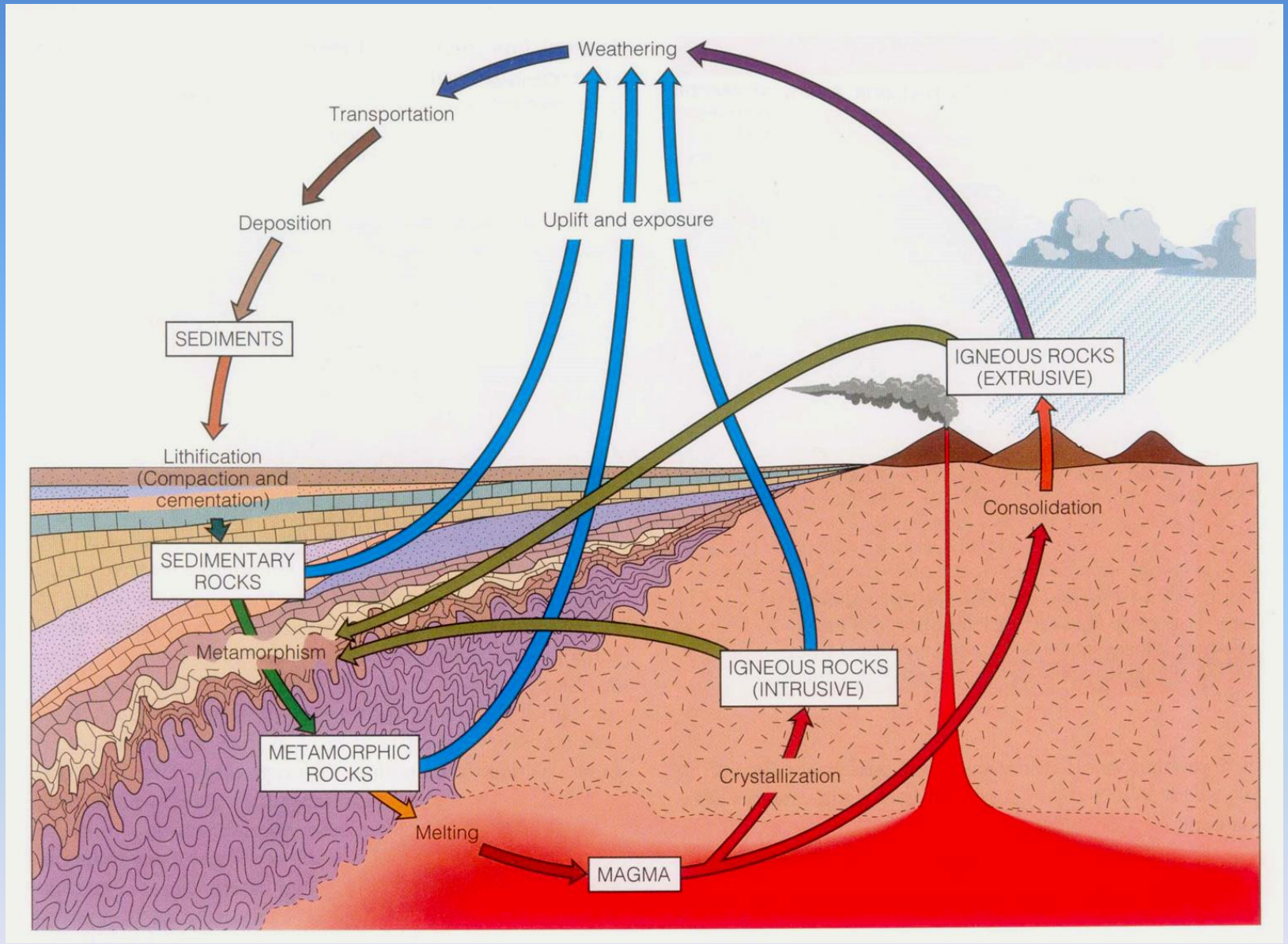


Fig. 1.12: The rock cycle showing the interrelationship between Earth's internal and external processes and how each of the three major rock groups is related to the others. (Modified from Fig. 12, Dietrich, R.V. 1979, Geology and Michigan: Forty-nine Questions and Answers)

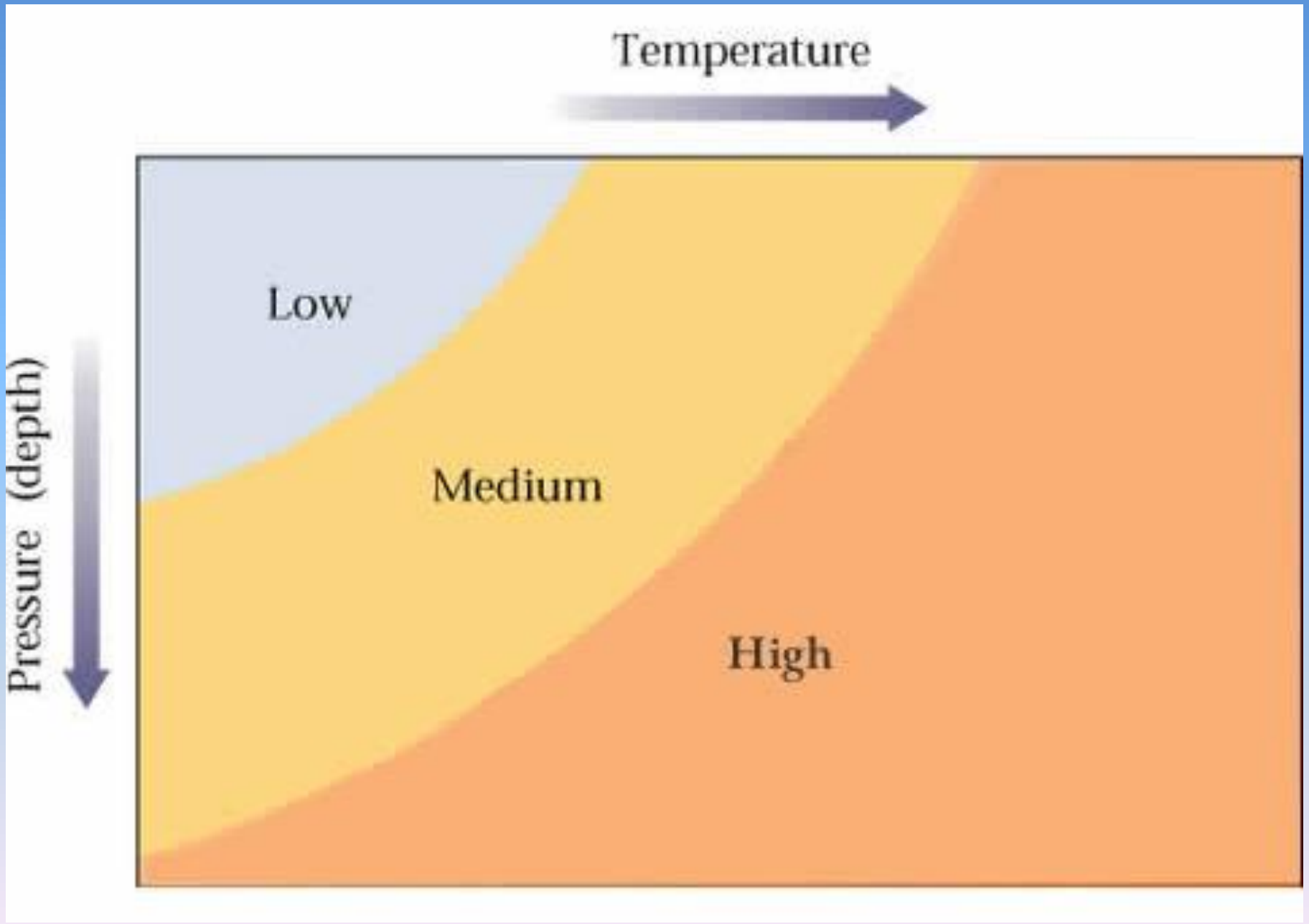
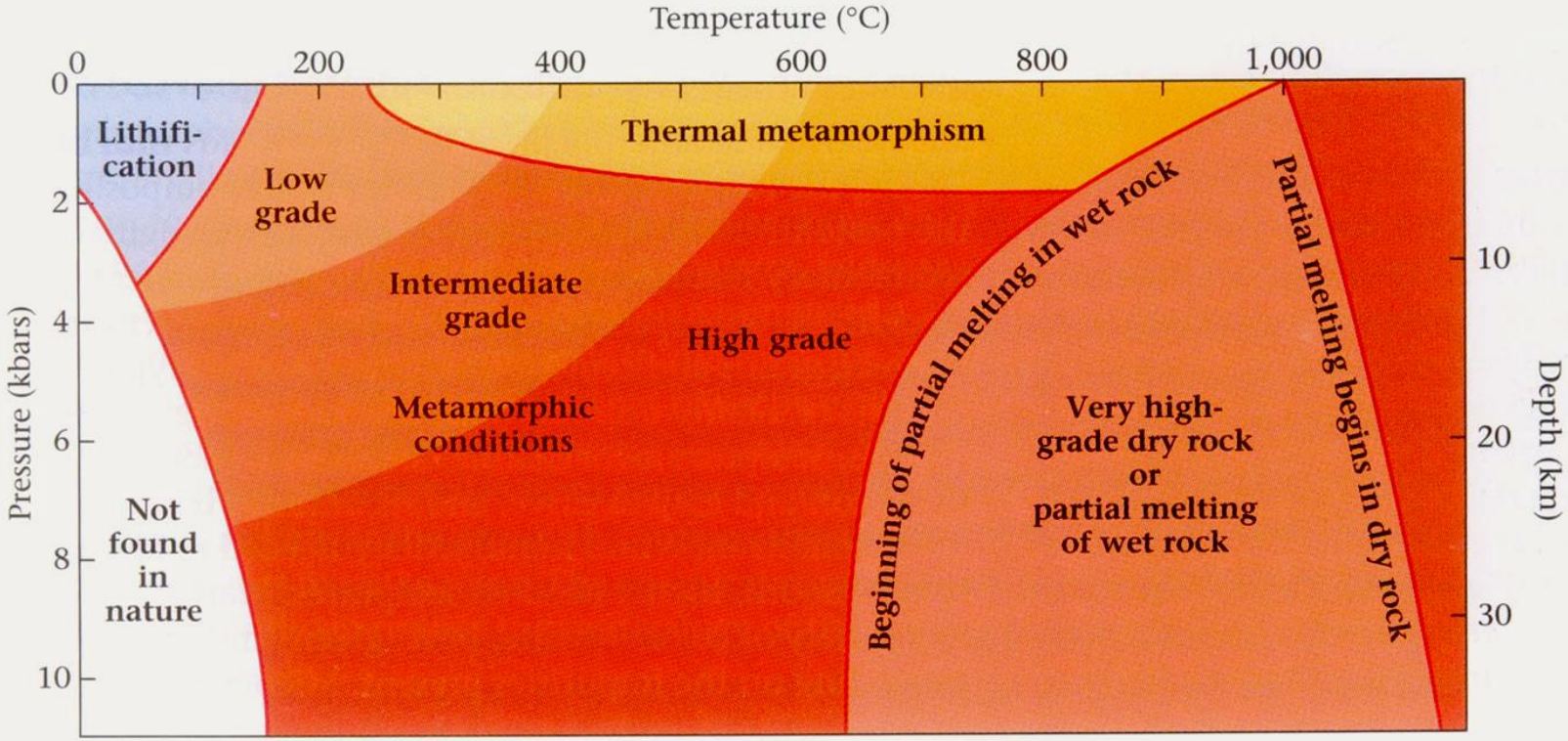
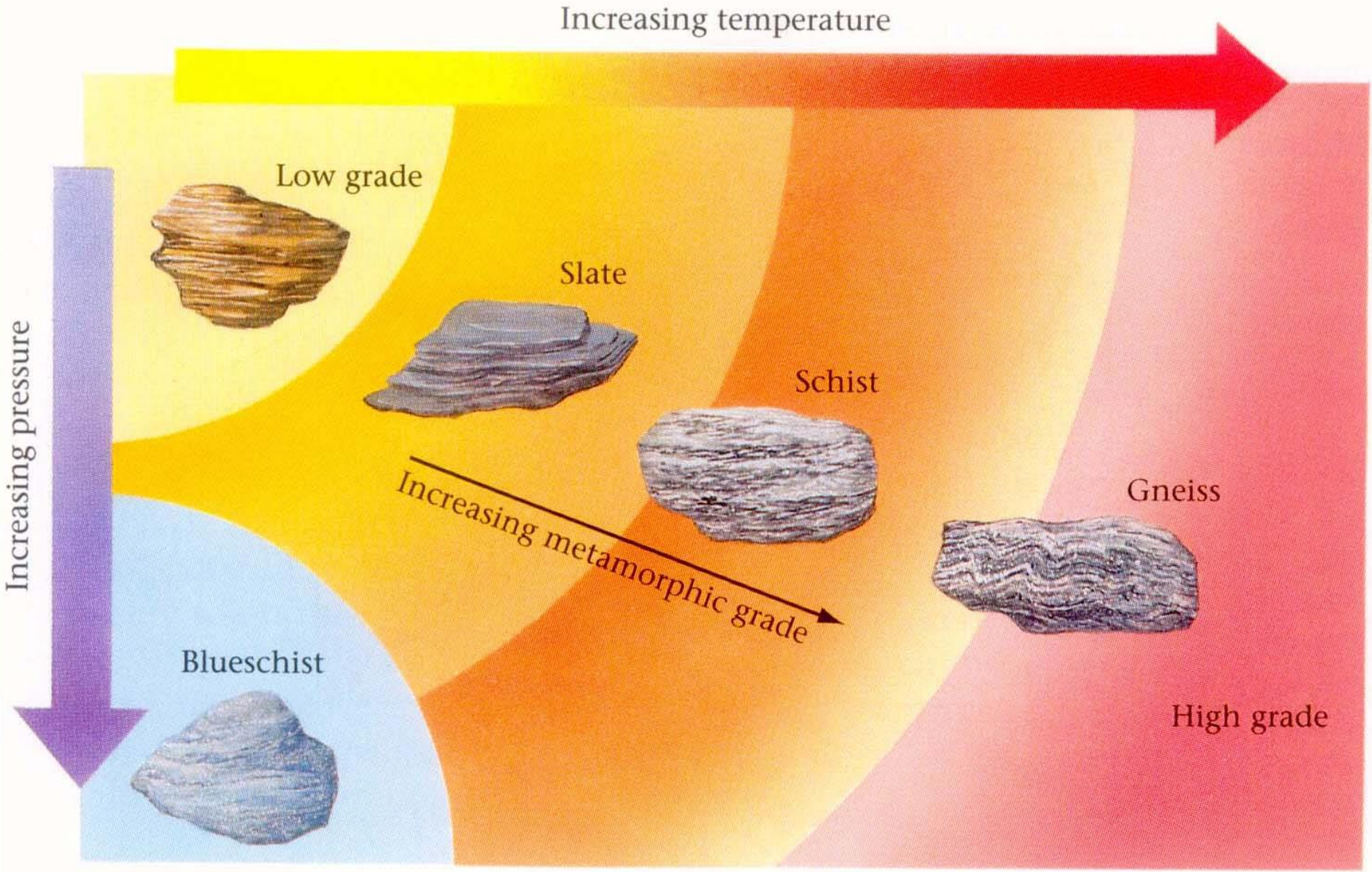

Temperature
Pressure (depth)
Low
Medium
High

FIGURE 8.18 The conditions of pressure and temperature under which metamorphism occurs. At low pressures and temperatures, only lithification takes place. At progressively higher pressures and temperatures, a rock passes from low to medium to high grade. If the temperature increases but the pressure stays low, we call the metamorphism "thermal." If the rock contains water, it begins to melt at the upper limit of high-grade metamorphism, but if it does not contain water, melting doesn't begin until higher temperatures.




Increasing temperature
Increasing pressure
Low grade
Slate
Schist
Gneiss
Blueschist
Increasing metamorphic grade
High grade

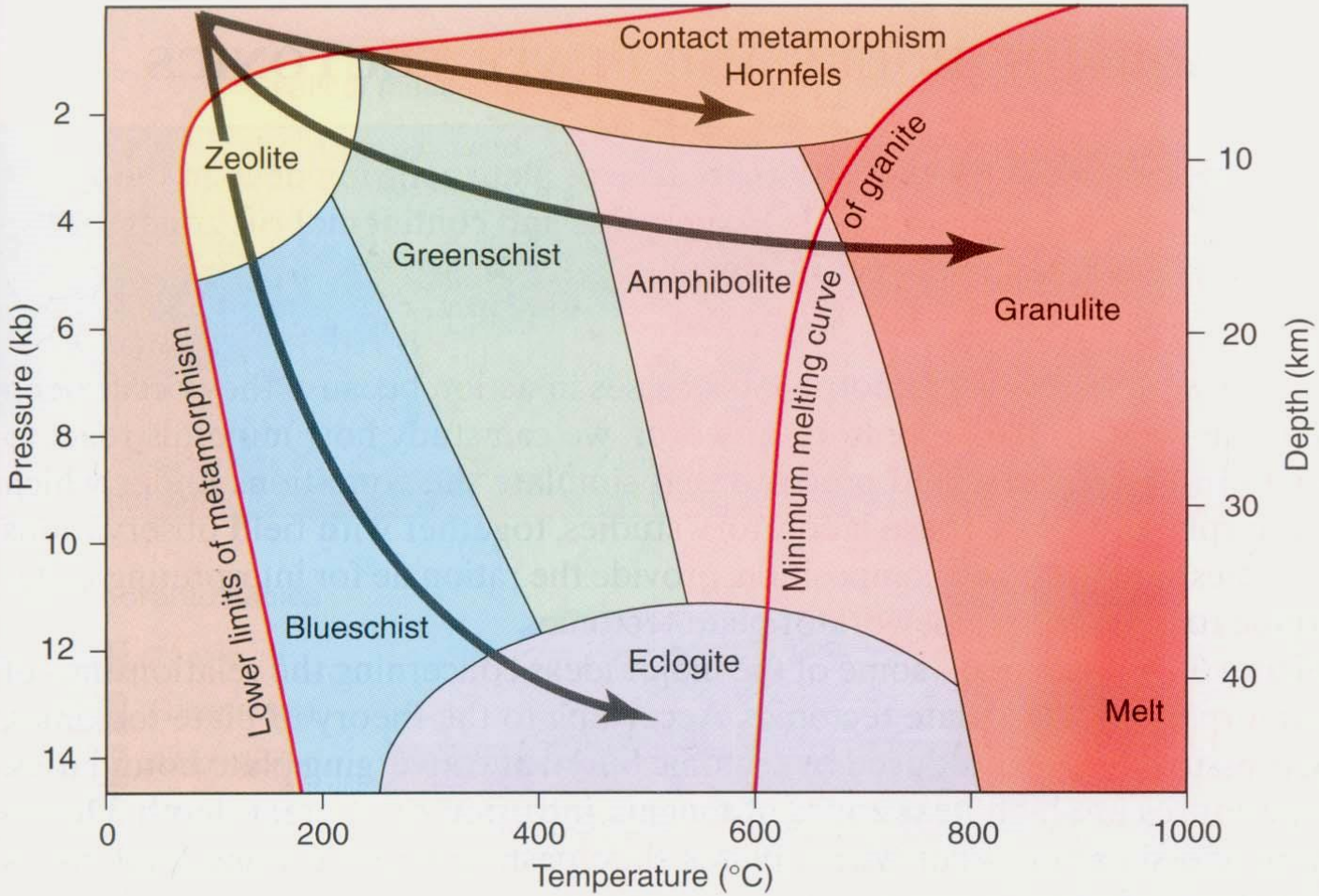


FIGURE 6.15 **Metamorphic facies** are defined by a set of minerals stable at a certain temperature and pressure (depth) and independent of rock composition. The arrows show three possible paths of metamorphism. If temperature increased moderately with pressure, the sequence of facies would be zeolite, greenschist, amphibolite, and granulite (the middle arrow). If the increase in temperature with depth was slight, changes in metamorphic facies would follow the path indicated by the lower arrow, with the formation of blueschist and then eclogite. Contact metamorphism is limited to zones of low pressure around shallow igneous intrusions (the upper arrow).

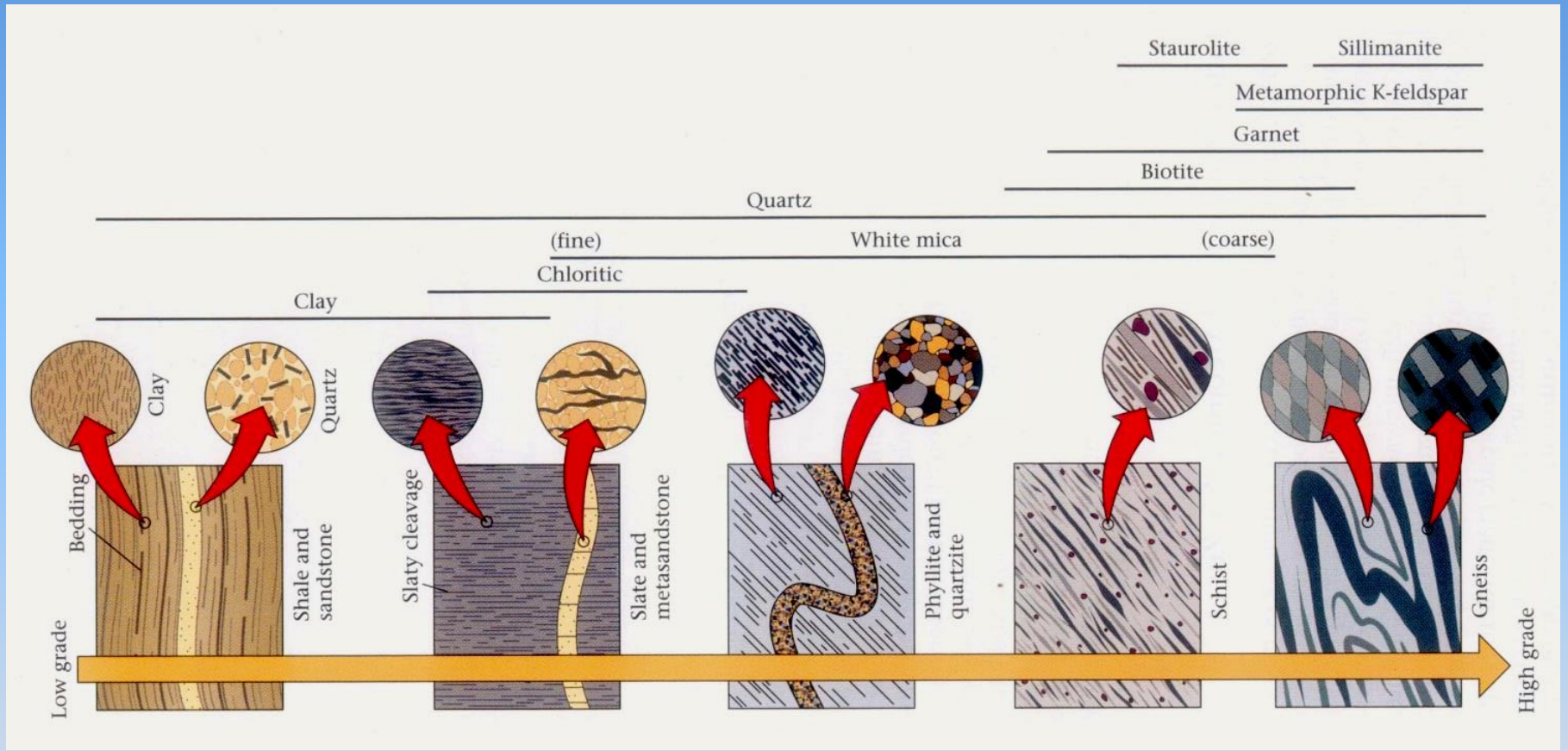


Fig. 8.19: When shale progressively metamorphoses from low grade to high grade, it first becomes slate, then phyllite, then schist, then gneiss. In may cases, gneiss and schist can from under the same conditions. The side graph shows the stability range of various minerals.

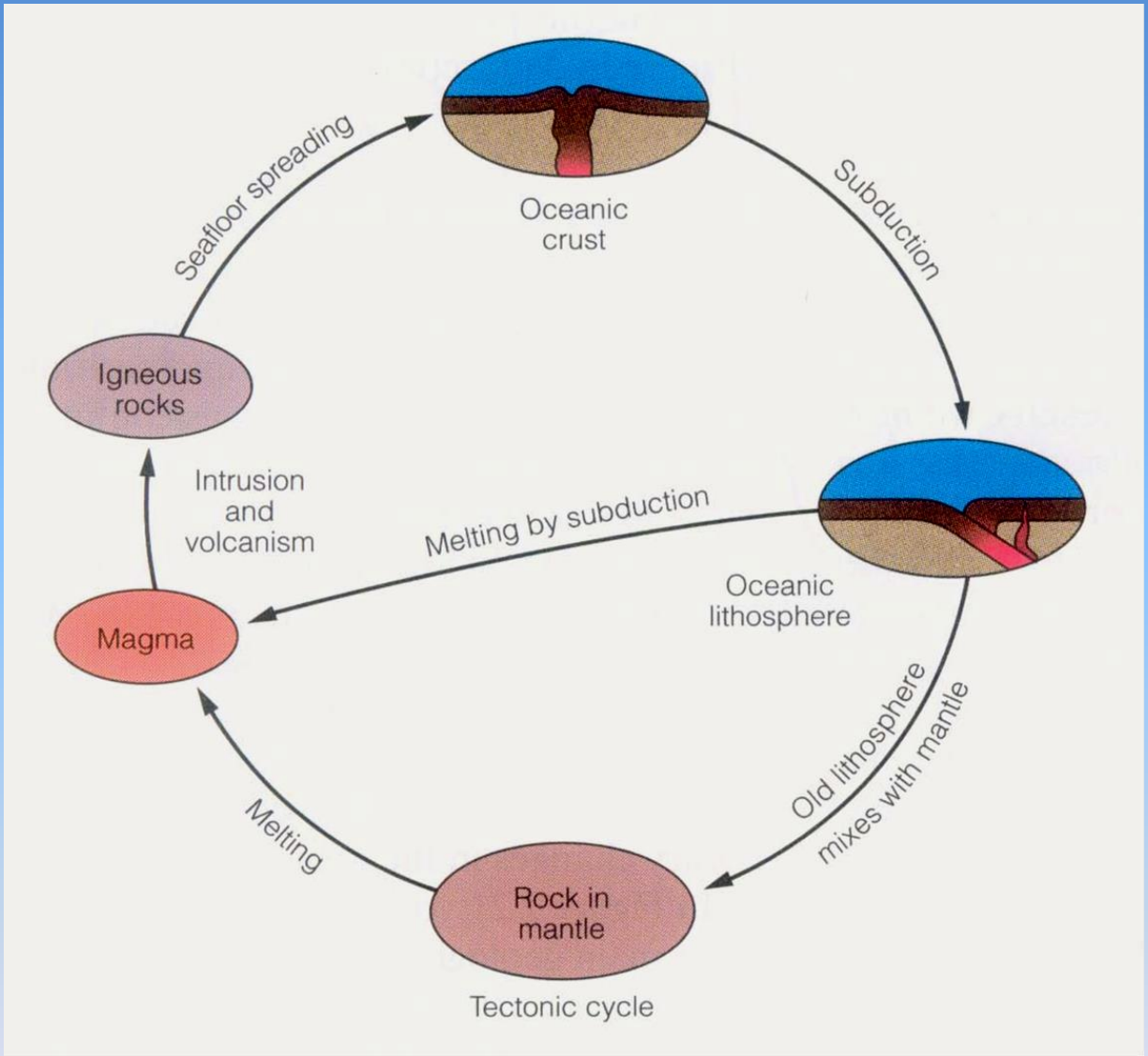
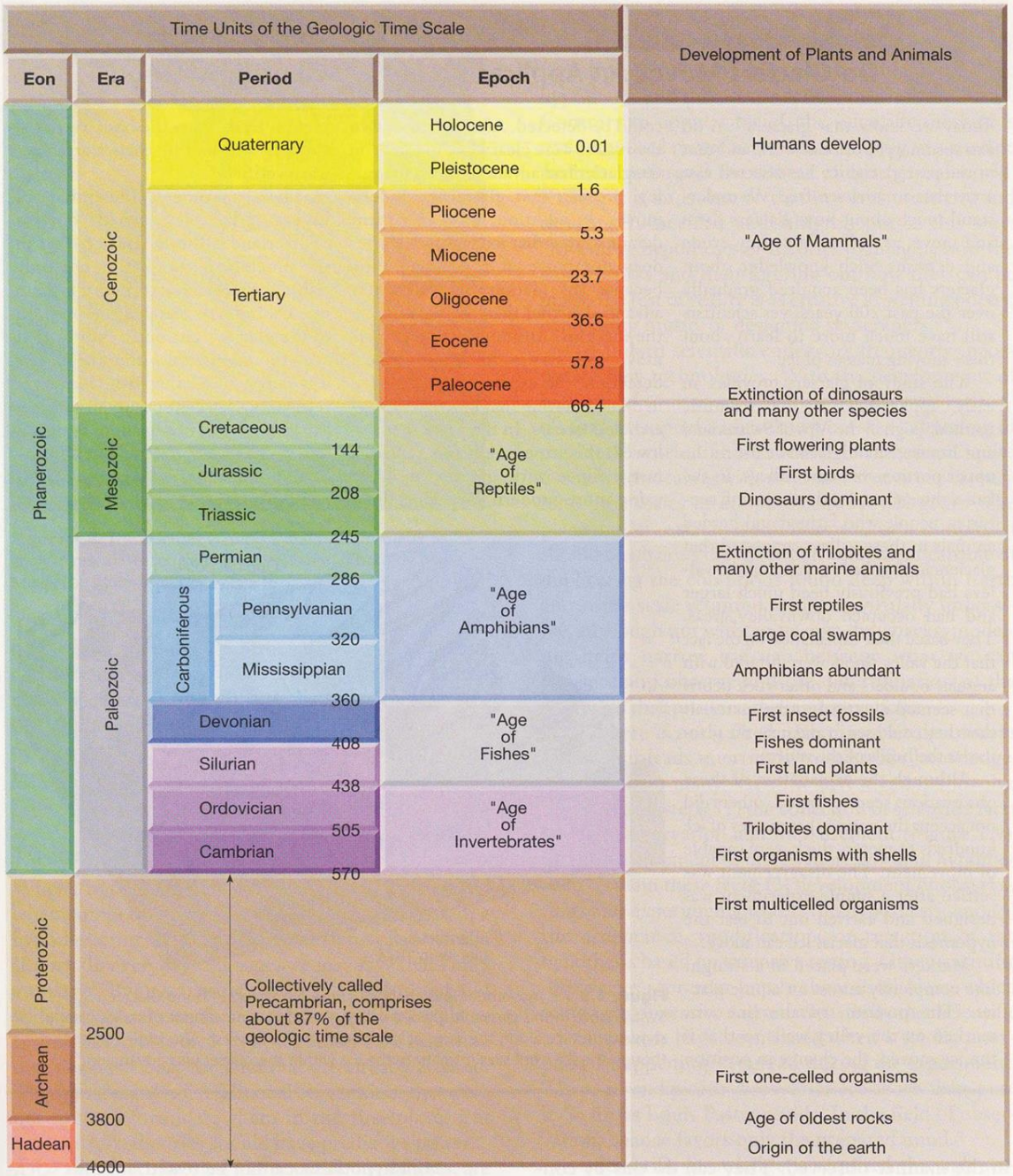
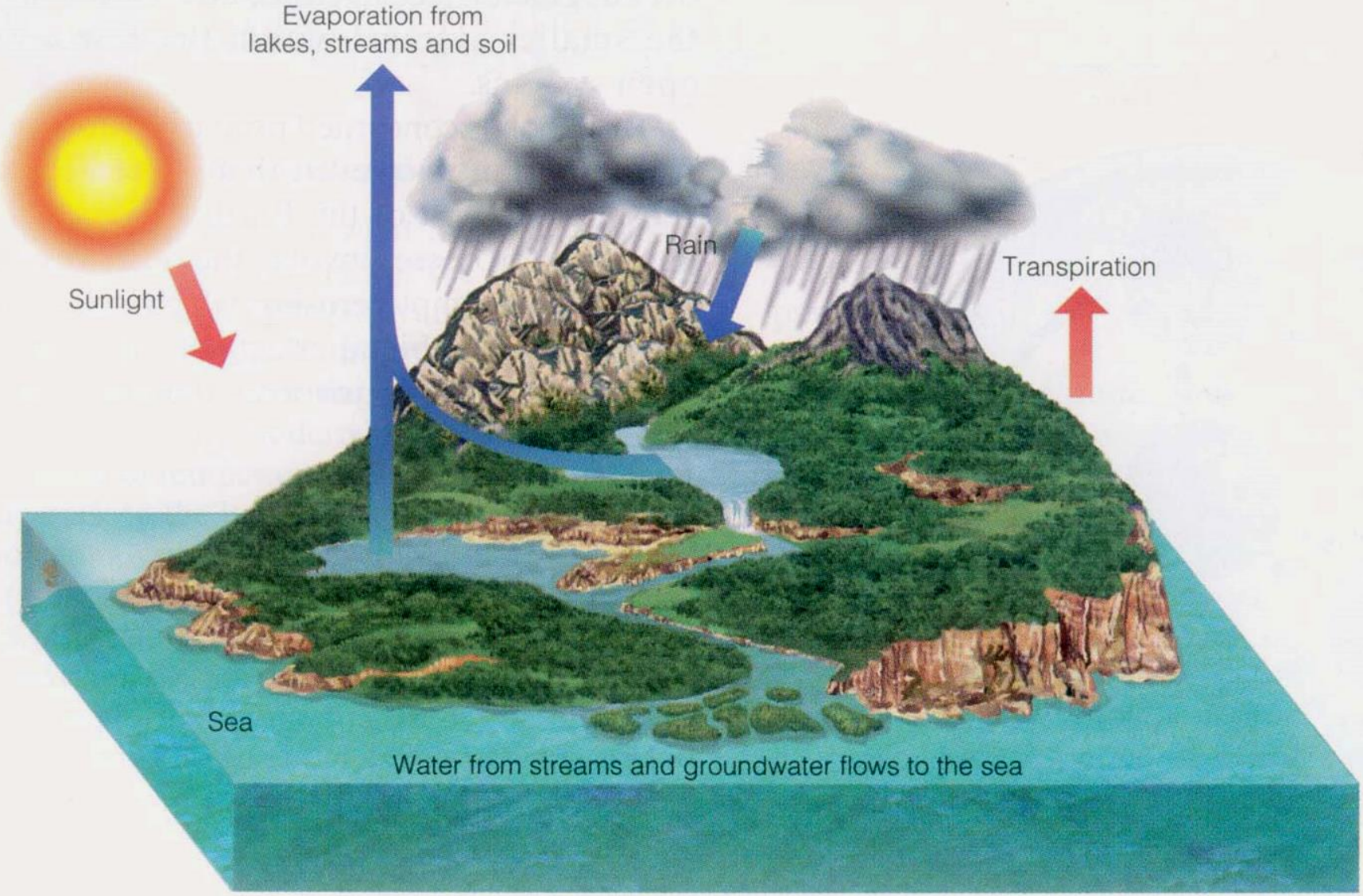


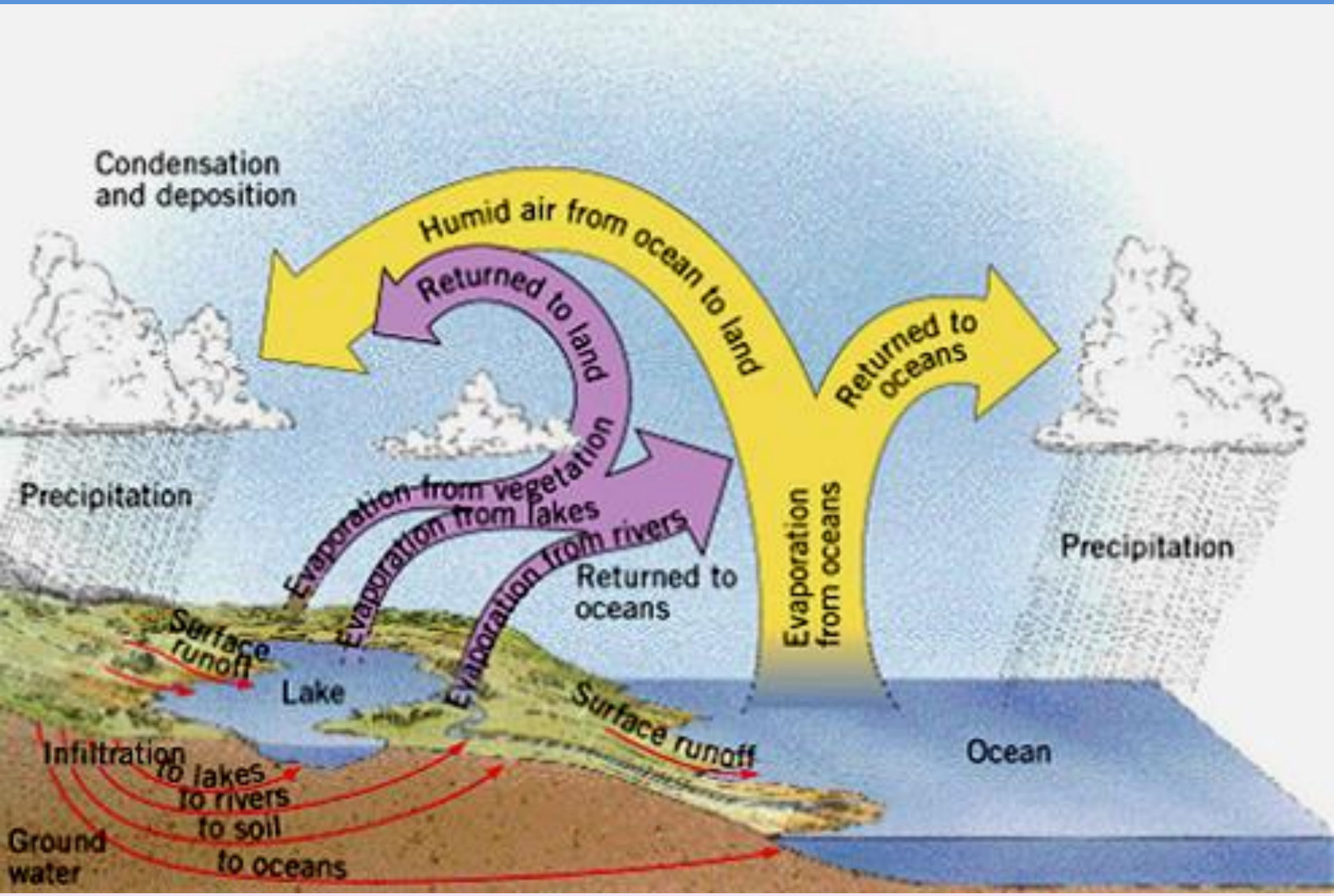
Fig. 2.20: The Tectonic Cycle: Processes driven by the Earth's geothermal energy power the tectonic cycle. Rock in the mantle melts and the magma rises to make new oceanic crust. Eventually, the oceanic crust is subducted, which causes partial melting of the mantle rocks in contact with the subducting lithosphere capped by oceanic crust. This magma, in turn, rises to create volcanoes.

Thank you



The geologic time scale. Numbers on the time scale represent time in millions of years before the present. These dates were added long after the time scale had been established using relative dating techniques. The Precambrian accounts for more than 85 percent of geologic time. (Data from Geological Society of America)


Evaporation from
lakes, streams and soil
Sunlight
Rain
Transpiration
Sea
Water from streams and groundwater flows to the sea


Condensation and deposition
Humid air from ocean to land
Returned to land
Returned to oceans
Precipitation
Evaporation from vegetation
Evaporation from lakes
Evaporation from rivers
Returned to oceans
Evaporation from oceans
Precipitation
Surface runoff
Lake
Surface runoff
Ocean
Infiltration
to lakes
to rivers
to soil
to oceans
Ground water

Age of earth given in Bible

Calculated by Irish Archbishop James Ushers

The earth originated precisely at night fall before Sunday on 23rd of October, 4004 BC.