Glaciers, streams, earthquakes, and the formation of the Appalachian Mountains

WEEK 7:

The Formation of Mountains

JUNE 8, 2023

Please do not hesitate to INTERUPT ME AS I AM SPEAKING!

If you wish to:

ask a question;

make a comment;

correct me.

To do so, simply blurt out something like: Hey Richard, what about - - -.

There are many mountains and mountain ranges.

Today we are going to look at some of these mountains and mountain ranges

and see how they were formed.

There are six basic kinds of mountains.
Each one of these is made a different way.
These six are:

Dome (Domal) Mountains

Fault-block Mountains

Volcanic Mountains.

Plateau Mountains.

Shield Mountains

Folded(Fold Back) Mountains

Who among you has gone to the motorcycle rally in Sturges, South Dakota?



The city of Sturgis, S.D. is located in the far west part of South Dakota, just next to the BLACK HILLS.

The BLACK HILLS

are a type of mountain called

DOMAL MOUNTAINS

In 1874 ***Lt. Col. George Armstrong Custer*** was ordered to make an exploration of the BLACK HILLS inside the boundary of the Great Sioux Reservation.

During the exploration, geologists discovered deposits of gold on the reservation.

Word of the discovery of gold caused an invasion of miners and entrepreneurs to the Black Hills in direct violation of the treaty of 1868.

U.S. negotiated with the Lakota to purchase the Black Hills, but the offered price was rejected by the Lakota.

The climax came in the winter of 1875, when the Commissioner of Indian Affairs issued an ultimatum requiring all Sioux to leave their homes in the Black Hills area and report to a reservation by January 31, 1876.

The deadline came with virtually no response from the Indians, and matters were handed to the military.

(You know the rest of the story)

DOMAL MOUNTAINS.

are mountains which form over an area of heat.

This heat below the ground caused the granite rocks to expand and be pushed up, forming a dome*, hence the name.

* This MAY be true.

A photo of the Black Hills (mountains) in south west South Dakota. These mountains are Domal mountains. In this instance the dome is ~150 X ~50 miles in size.

Note the flat terrain This flat terrain, consisting of miles and miles and miles of rolling hills surrounds this entire dome.
The dome part itself is made of Granite.




Spearfish
Bear Butte State Park
Sturgis
Devils Tower
Sundance
Lead
Deadwood
SOUTH DAKOTA
WYOMING
BLACK HILLS NATIONAL FOREST
Rapid City
Mt. Rushmore
Keystone
Crazy Horse Memorial
Custer
Custer State Park
Badlands National Park
Wind Cave National Park
Pringle
MAP AREA
SOUTH DAKOTA
N
Miles
0
10
20

A view of a part of the Black Hills, composed of granite



Another view of a part of the Black Hills, a DOMAL MOUNTAIN



Next we are going to look at a type of mountains called the

FAULT_BLOCK MOUNTAINS

THEY ARE MAINLY LOCATED IN NEVADA.

In the distant past in the area we now call ***Nevada*** there existed **a high (elevated) plateau**.

*Eventually this **elevated plateau** was*

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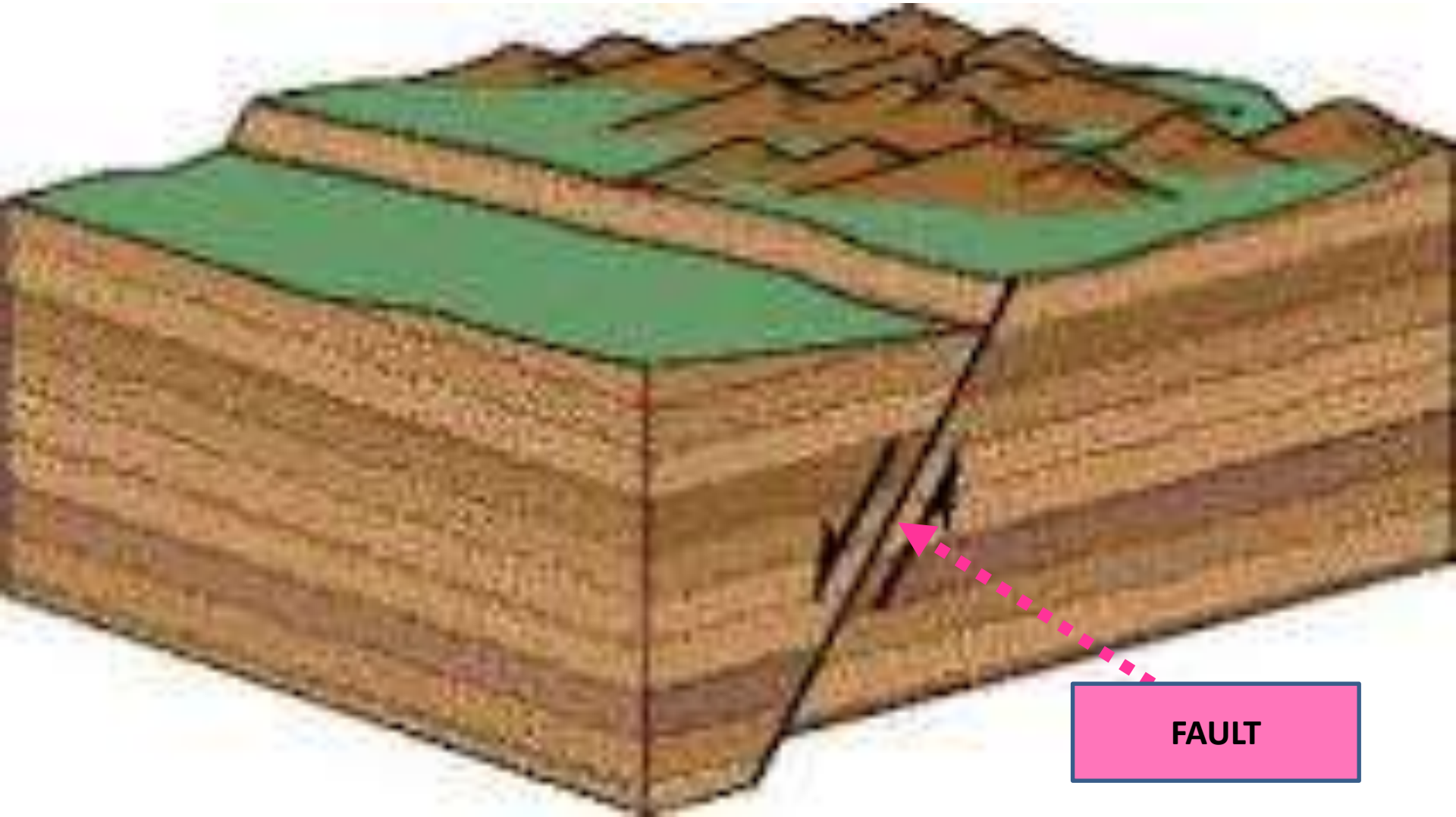
a p a r t.

*As a result of this stretching s*ome of the elevated plateau

cracked,

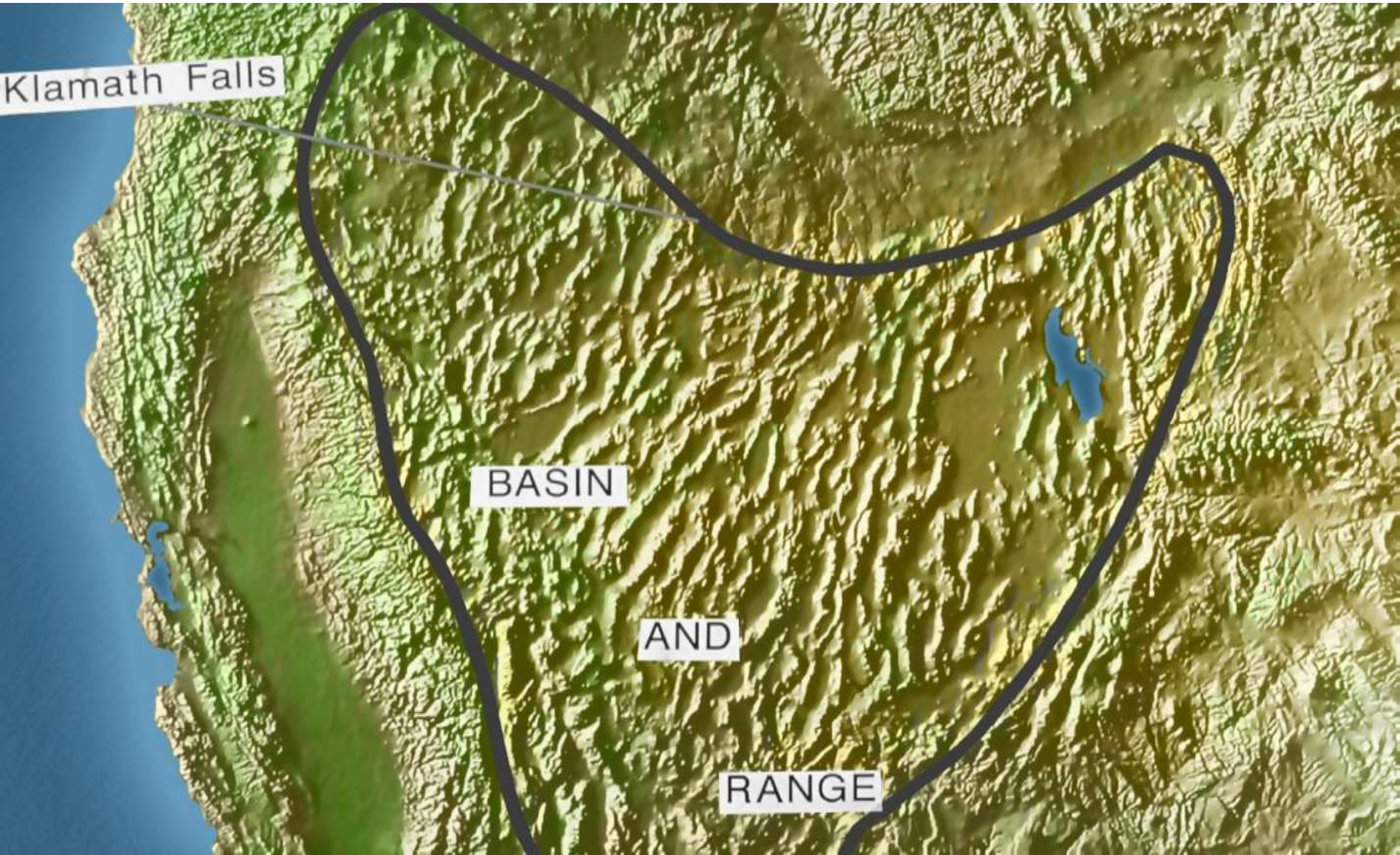
forming faults.

A fault is a crack in the Earth's crust.



We saw this image of the location of this area in Nevada a couple of weeks ago.
It is referred to as BASIN AND RANGE type of terrain.

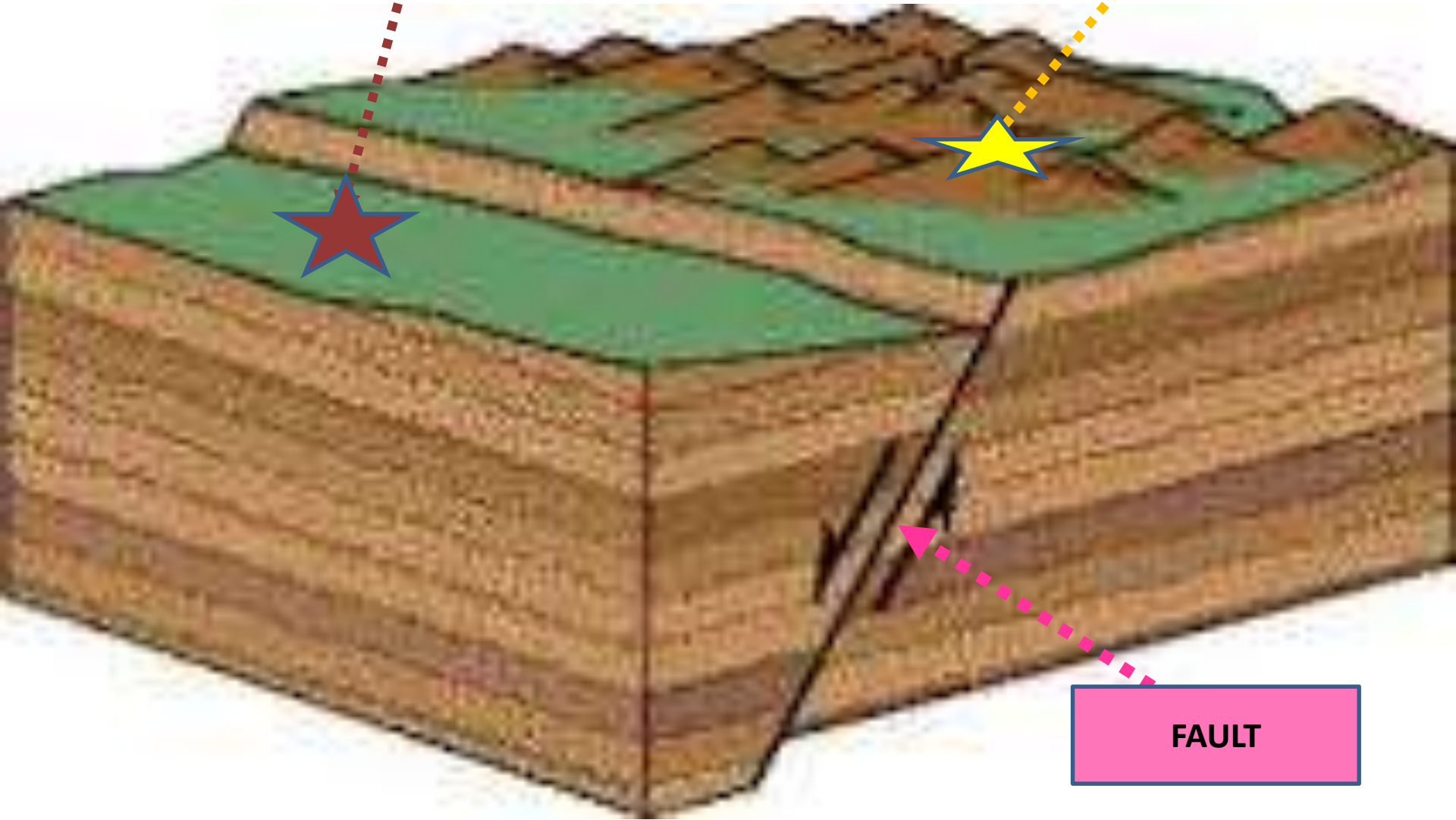
The types of mountains are referred to as: ***FAULT BLOCK*** mountains.



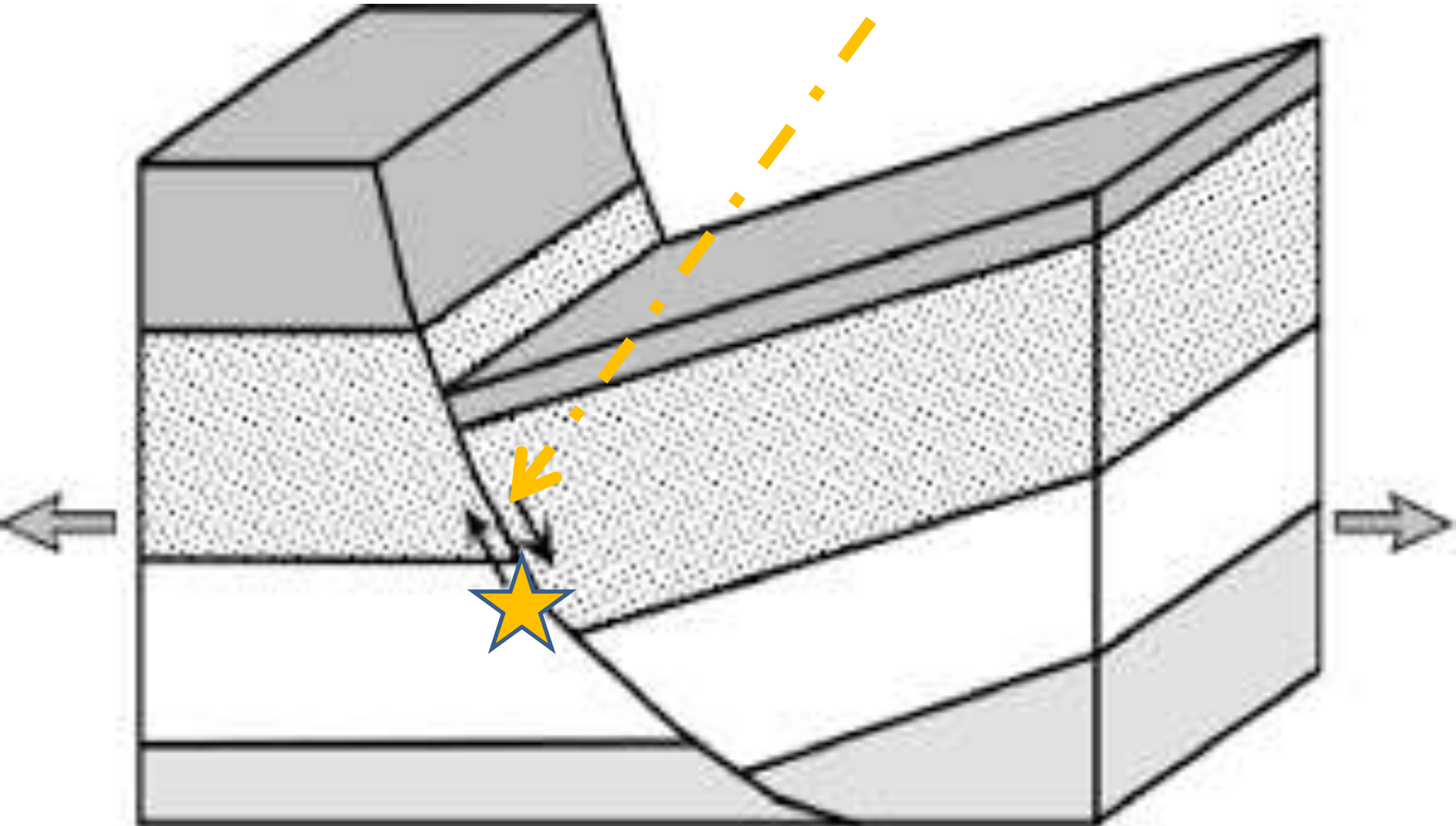
Parts of this plateau broke off at the faults. The broken off part then slide down to become a valley.

The part of the plain that did ***not*** slide down (i.e. it remained elevated) now appears as a mountain range.

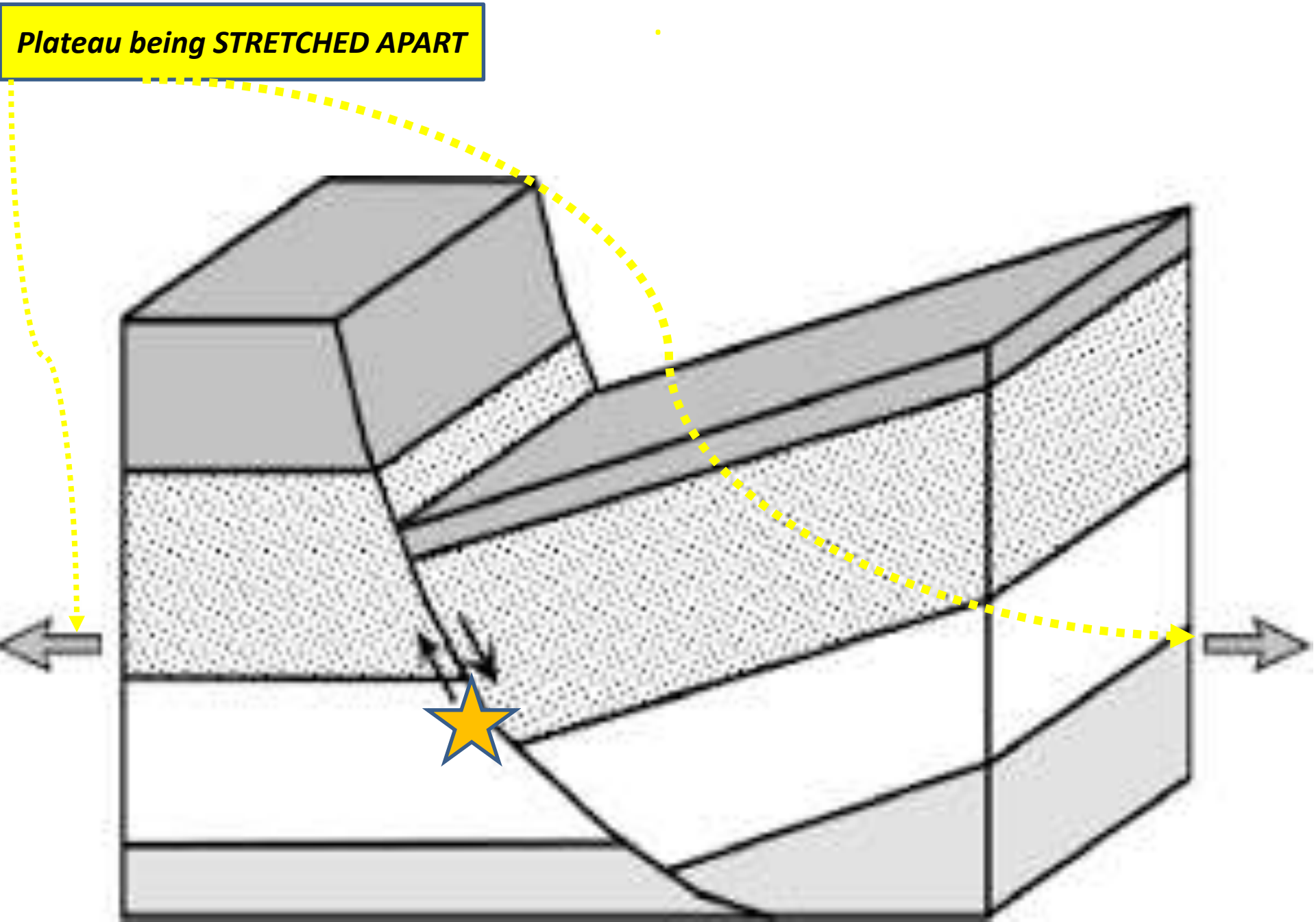
Here again we see the part of the plateau that slipped down to form a valley. However, now we also see the part of the plateau that remained elevated, forming mountains.



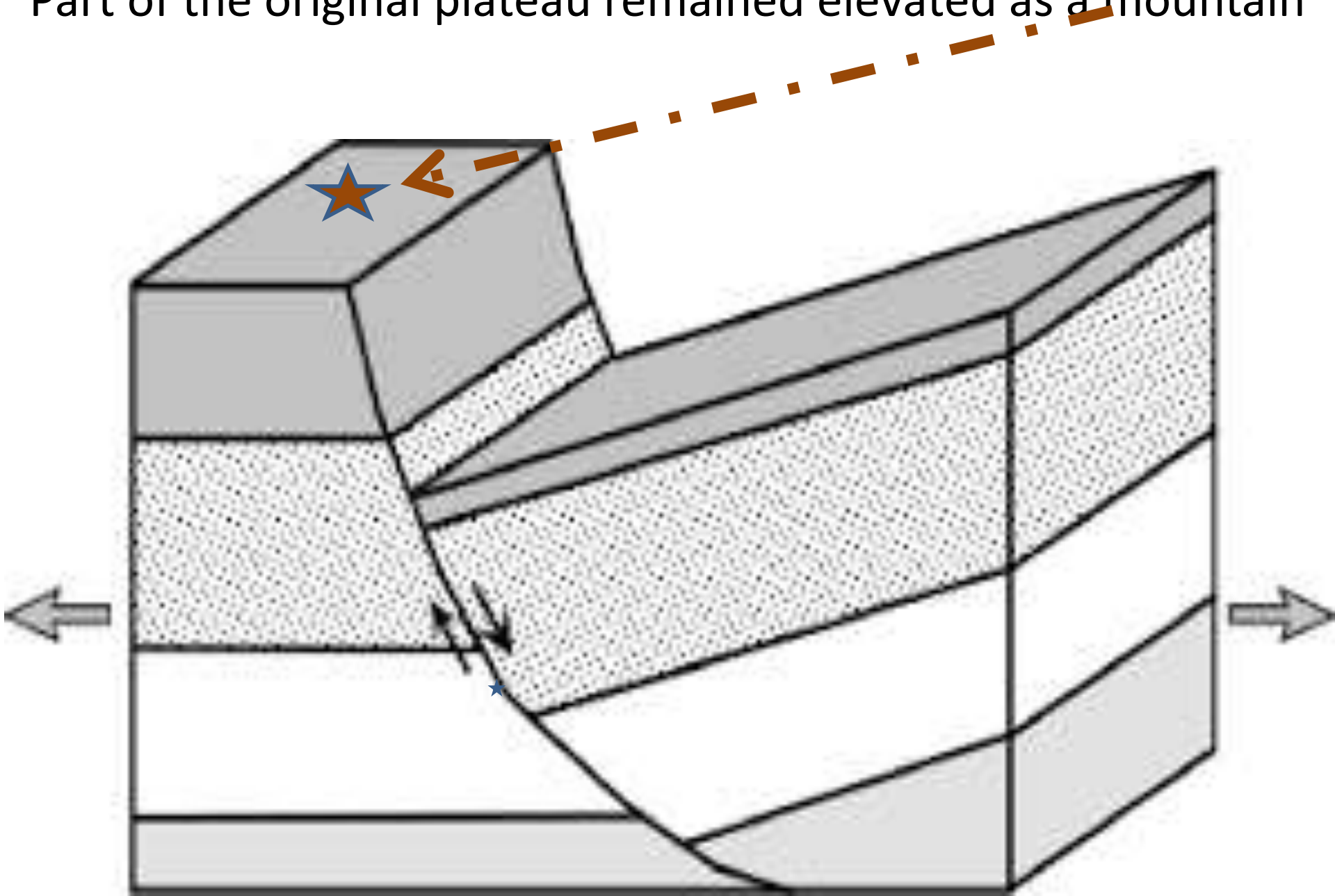
Here we see part of the earth falling along a ***fault***



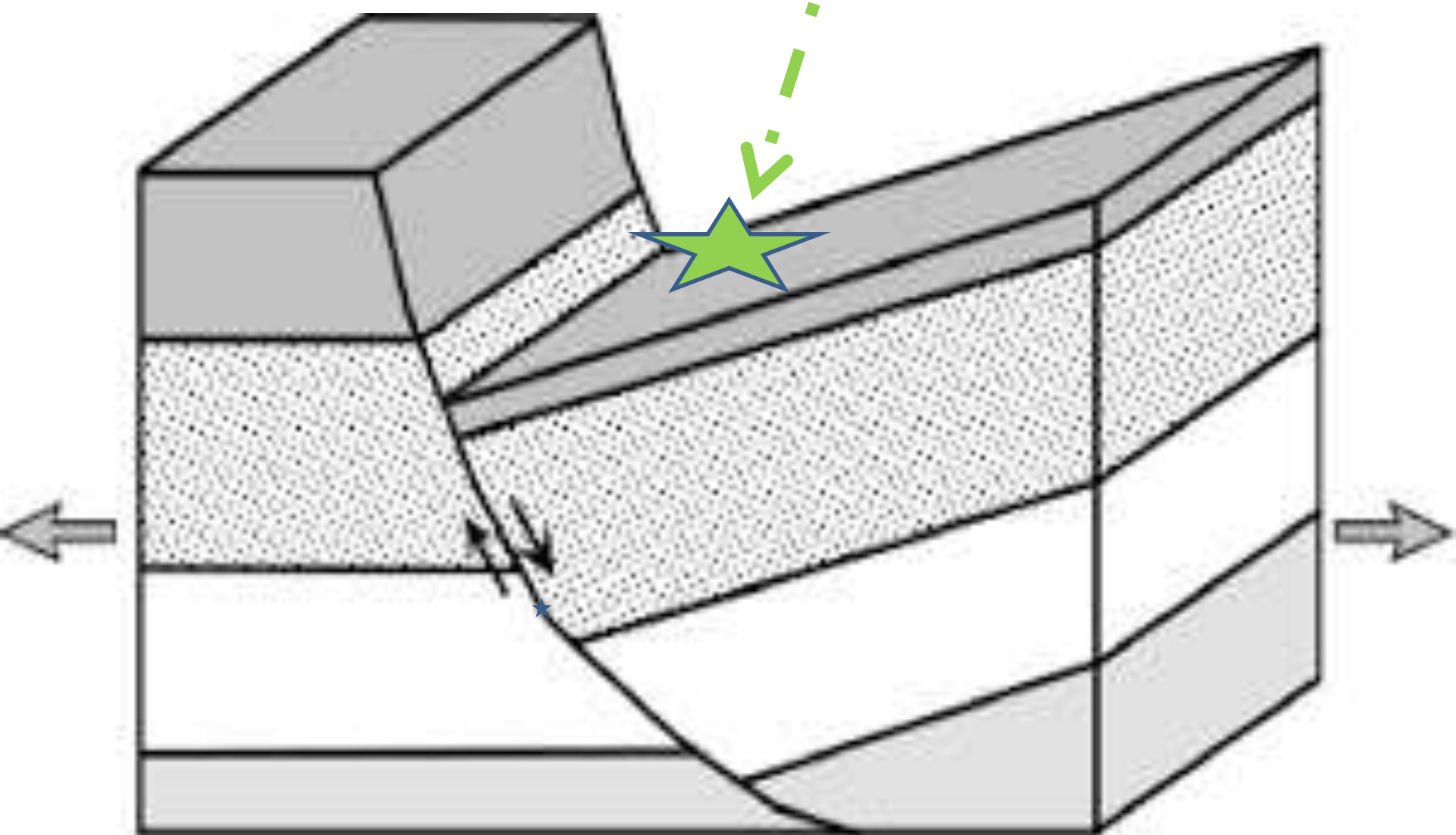
The part of the earth fell because the plateau was being pulled apart



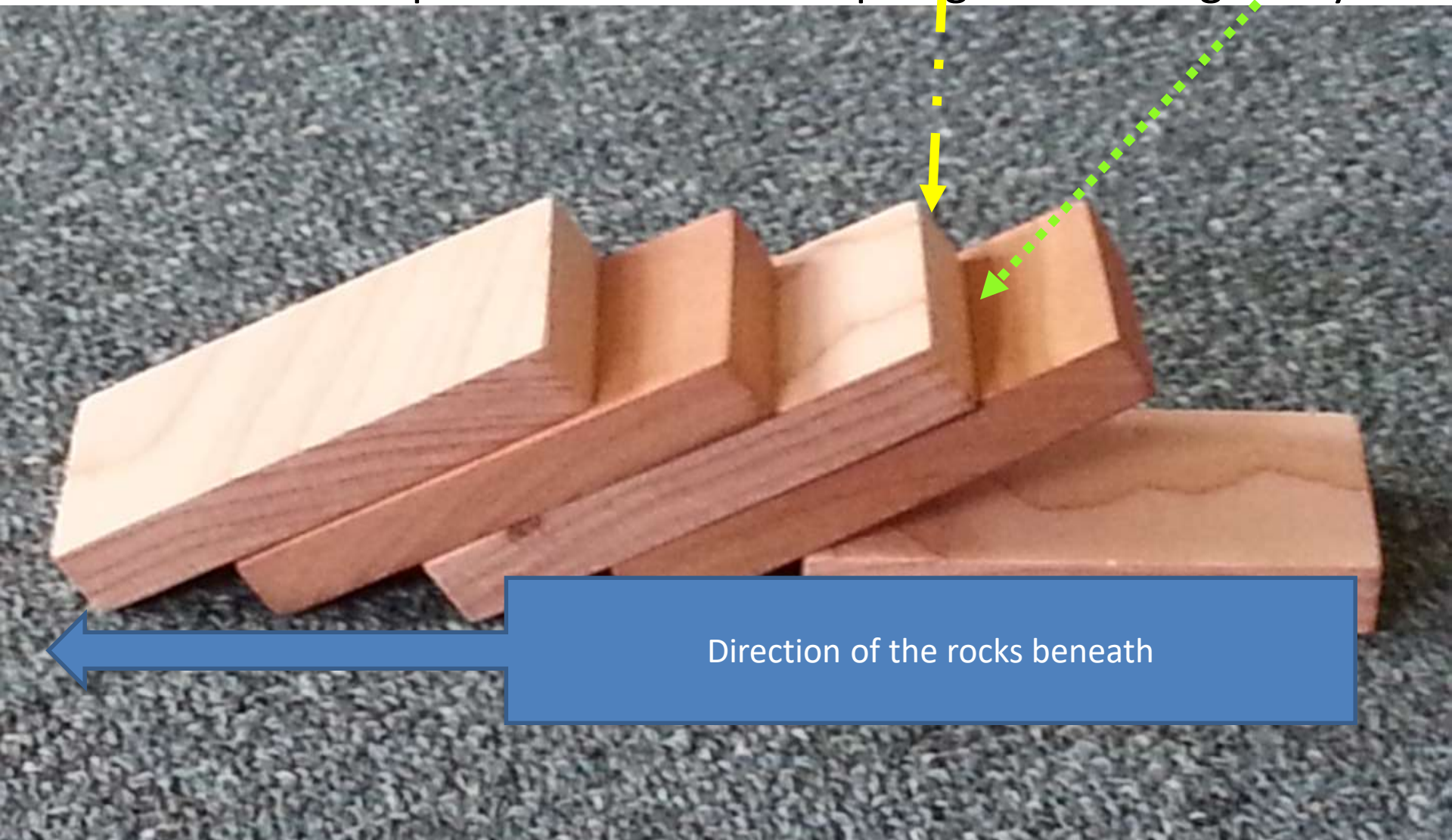
Part of the original plateau remained elevated as a mountain



Part of the original plateau slips down along the fault to become a VALLEY.

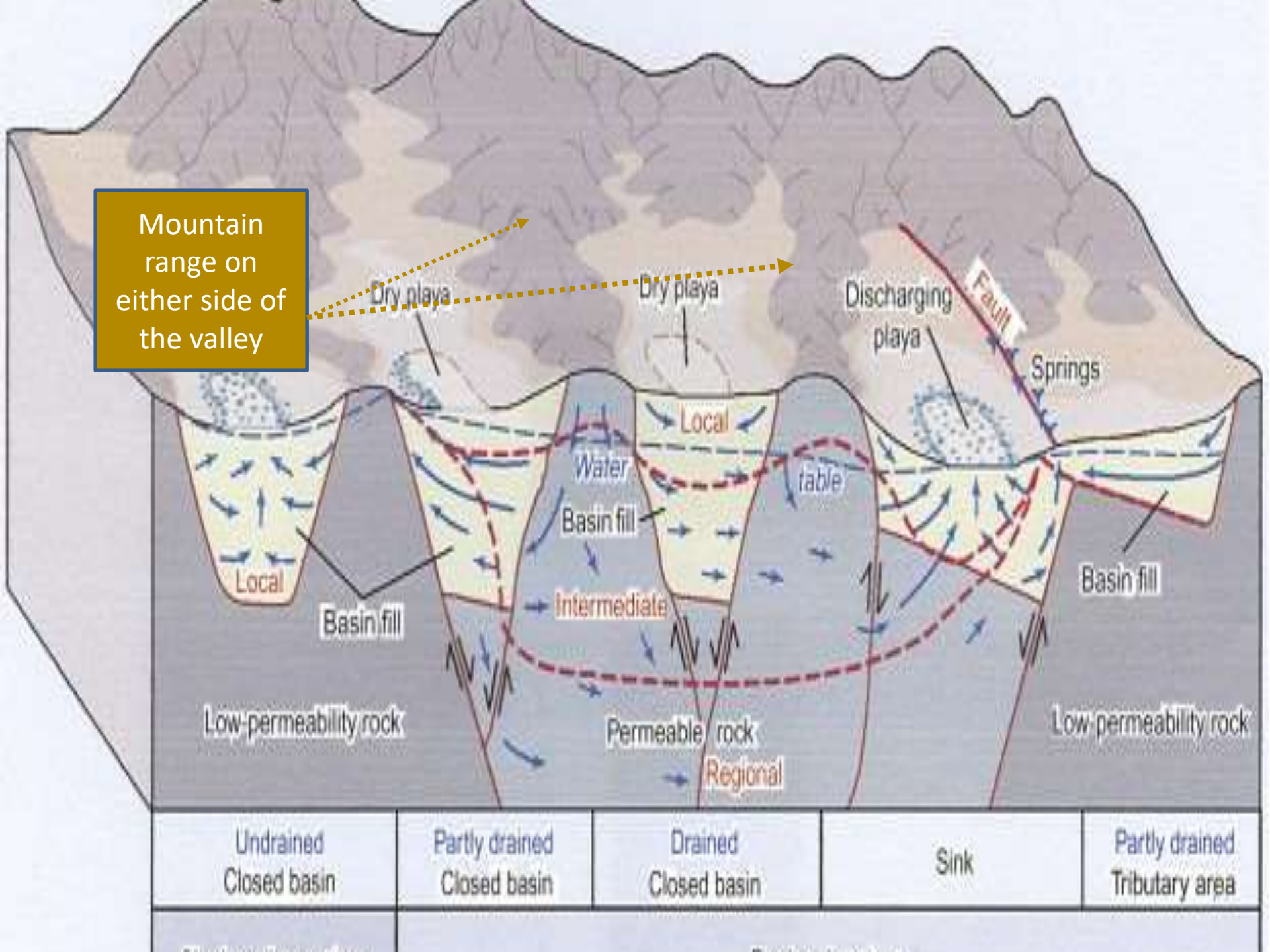


These 5 "**blocks**" were originally standing straight. The bottom of the blocks was then pulled, causing the blocks to topple over at their edges (fault lines). The ***top edge*** of each block becomes a long mountain. The spaces between the top edges form long valleys.

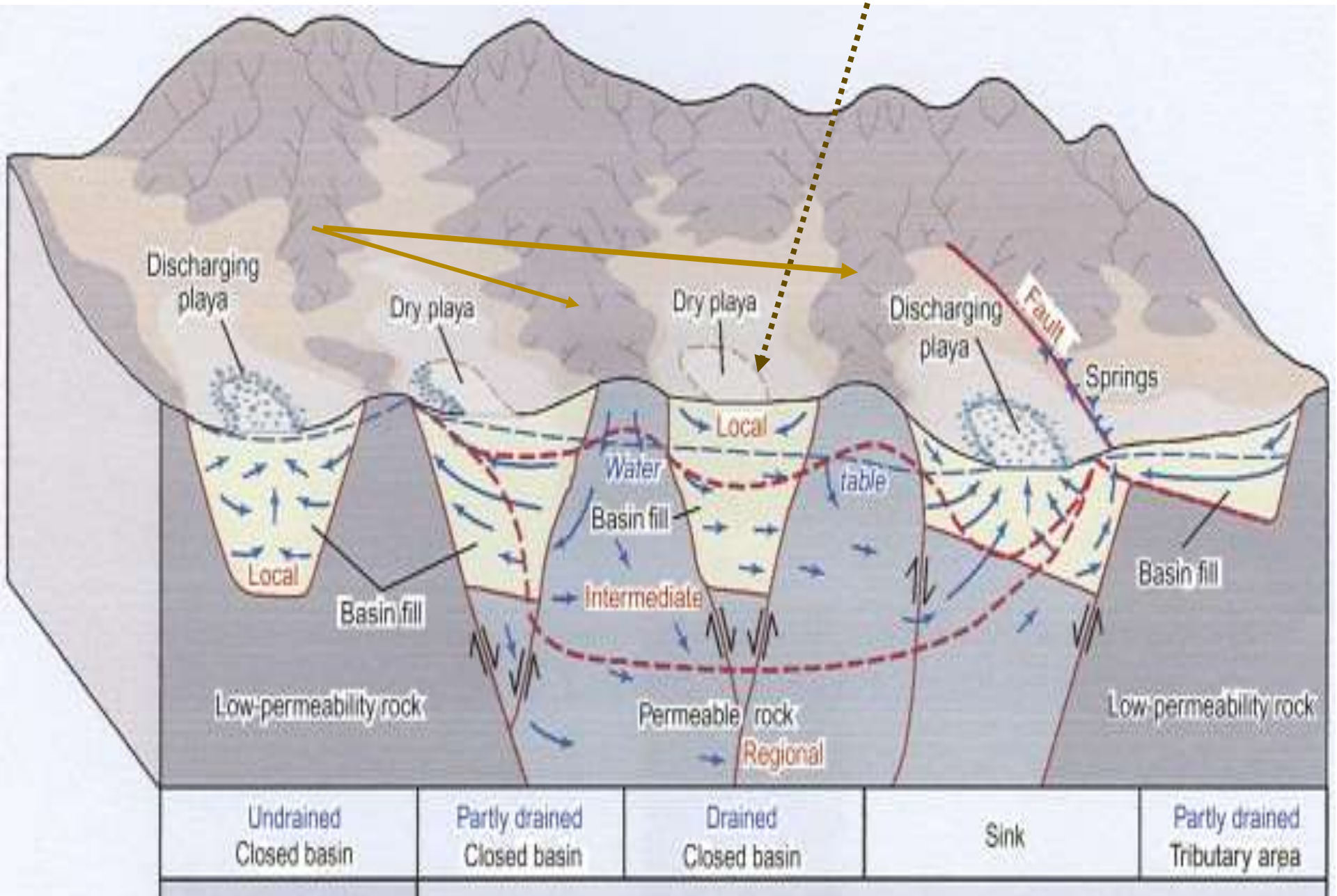


Over the years the mountains eroded

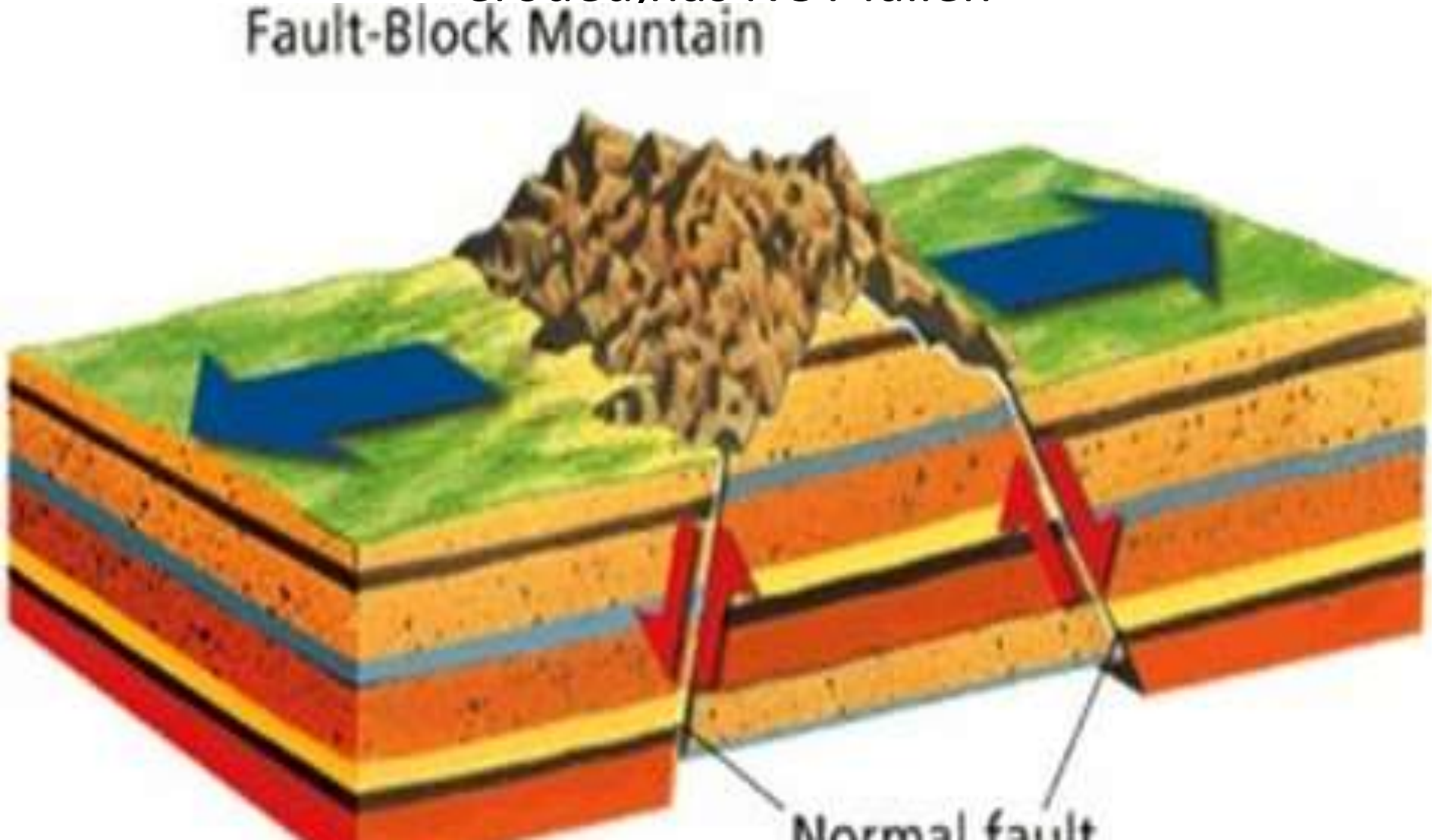
And the valleys became (somewhat) filled in with the eroded sediment .


Mountain range on either side of the valley
Dry playa
Dry playa
Discharging playa
Fault
Springs
Local
Water table
Basin fill
Local
Basin fill
Intermediate
Basin fill
Low-permeability rock
Permeable rock
Regional
Low-permeability rock
Undrained Closed basin
Partly drained Closed basin
Drained Closed basin
Sink
Partly drained Tributary area

One of these valleys could be **DEATH VALLEY.**



In this image ***we see*** that blocks of earth's crust have fallen along the fault lines, (because the crust has been pulled apart) while the center block of the crust ,now steeply eroded,has NOT fallen

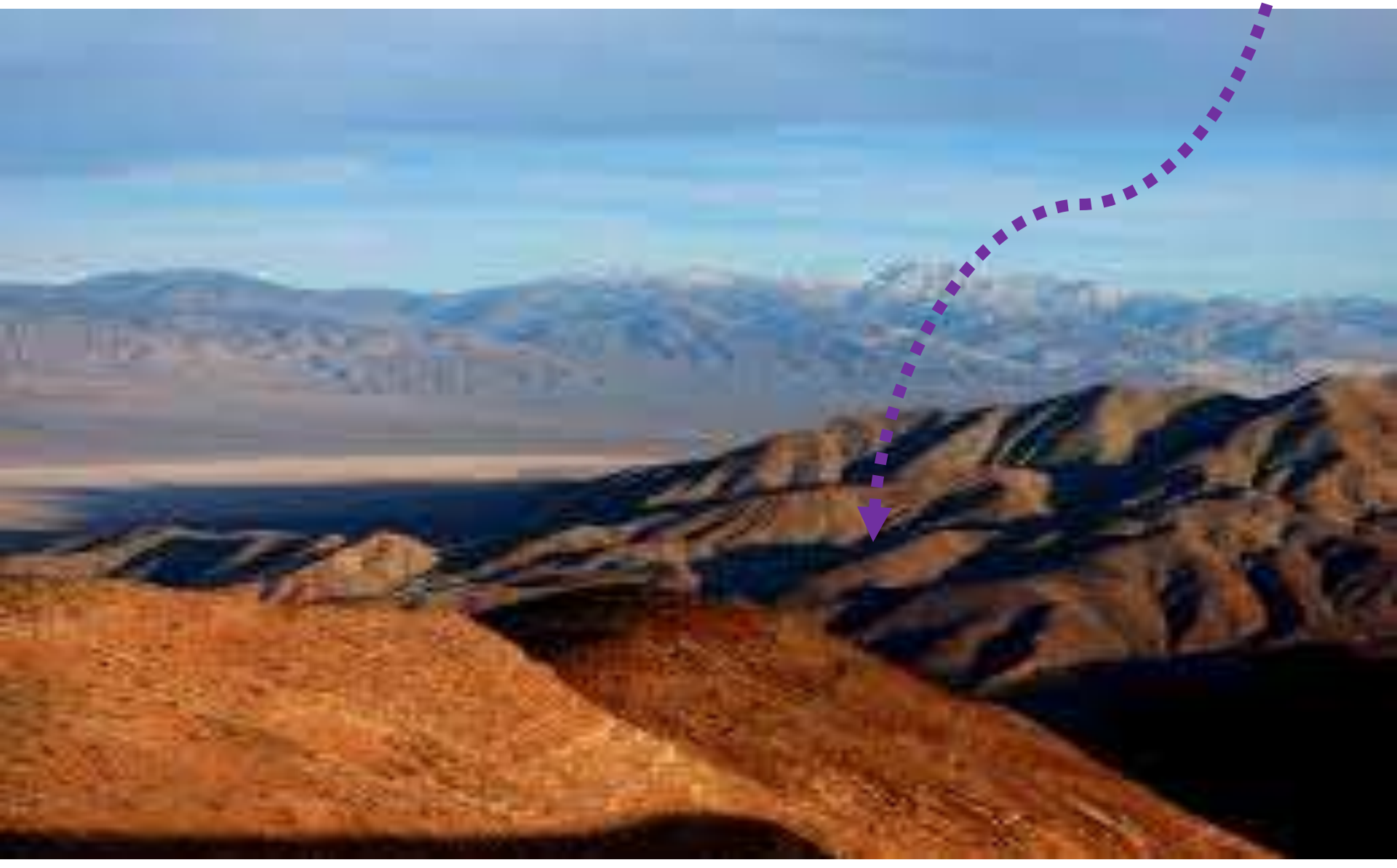


Here is a view of some of that ***Fault-Block mountain range*** on the <u>west</u> side of DEATH VALLEY and, **death *<u>valley</u>* itself.**



Here is a view of a section of the ***Fault-Block mountain range*** just east of DEATH VALLEY as well as the valley, in this case, **DEATH VALLEY.**

and the ***Fault-Block mountain range*** on the west side of DEATH VALLEY**.**



An areal view of some of the linear VALLEYS (BASINS) of the ***FAULT BLOCK mountains (RANGES)*** in Nevada.



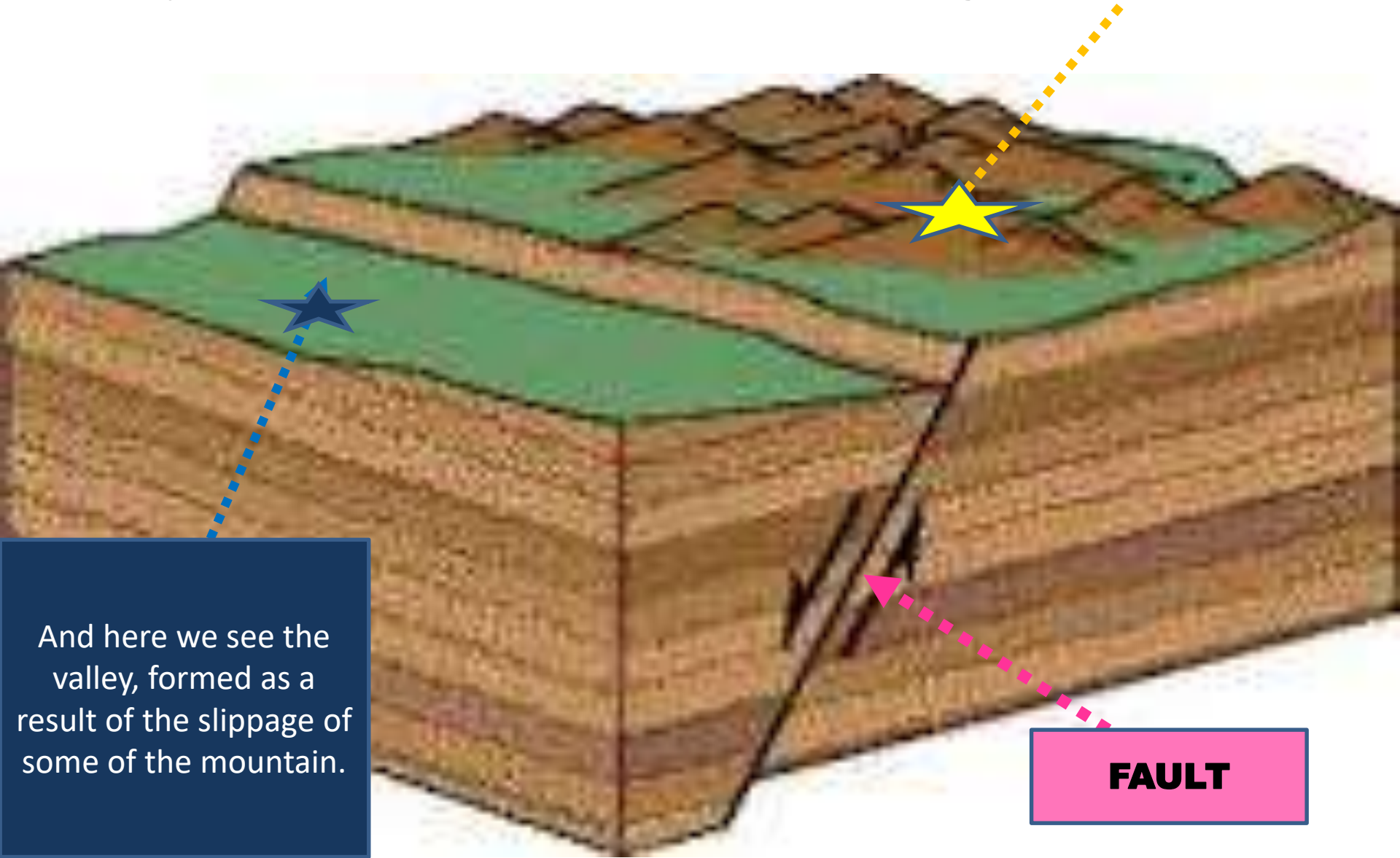
And if you drive to Las Vegas from the east at dusk you can seen the light from the sun shinning from behind the FAULT-BLOCK mountains west of town.



Here is a photo of the Grand Tetons near Yellowstone National Park.



Here again we see a part of a plateau that slipped down to form a valley. This time it is in Wyoming. Again we see the part of the plateau that remained elevated," forming" mountains.



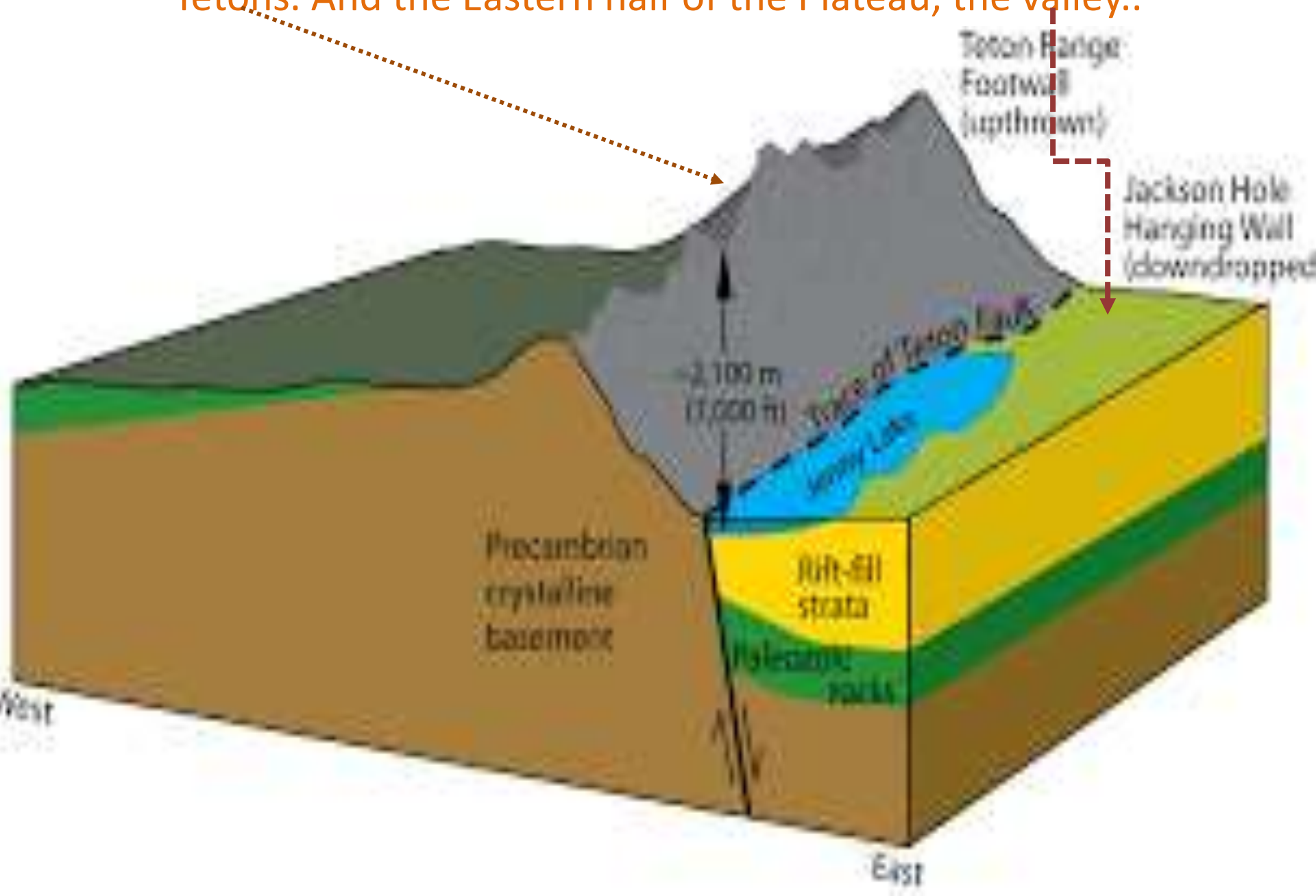
Between six and nine million years ago, *stretching and thinning* of the Earth's crust caused movement along the Teton fault.

The west block along the fault line remained elevated and formed the Teton Range.

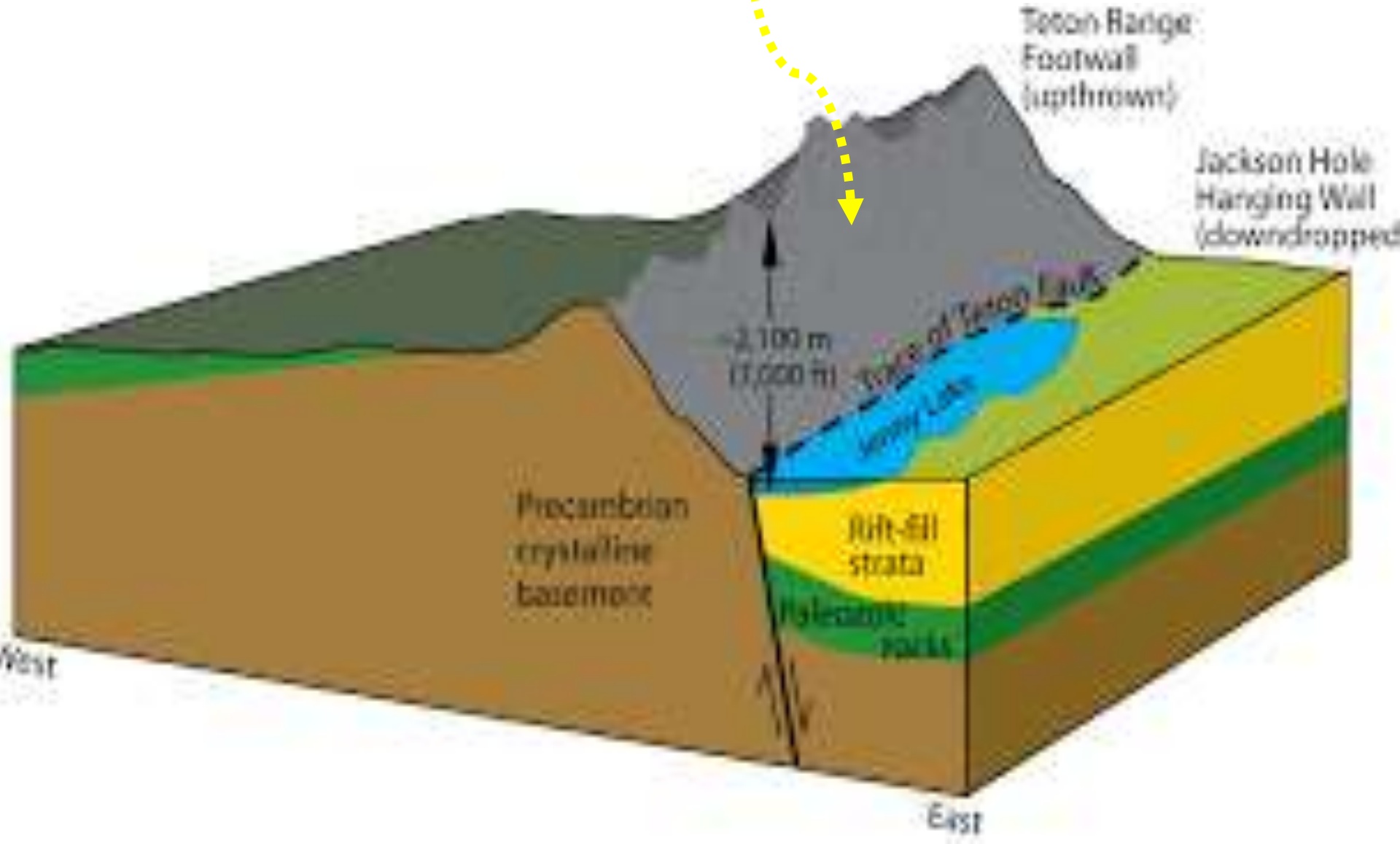
The fault's east block fell to form the valley called Jackson Hole.



Here is ***an image of*** the western part of the original plateau, The Grand Tetons. And the Eastern half of the Plateau, the valley..



Here, as with the Basin and Range, the Teton Mountain Range area was stretched apart. In so doing it “cracked”/formed a fault, the Eastern part of the fault slide down



Here is ***a photo of*** the city of Teton Village, located in **the valley** of the Eastern part of the Fault which has fallen.

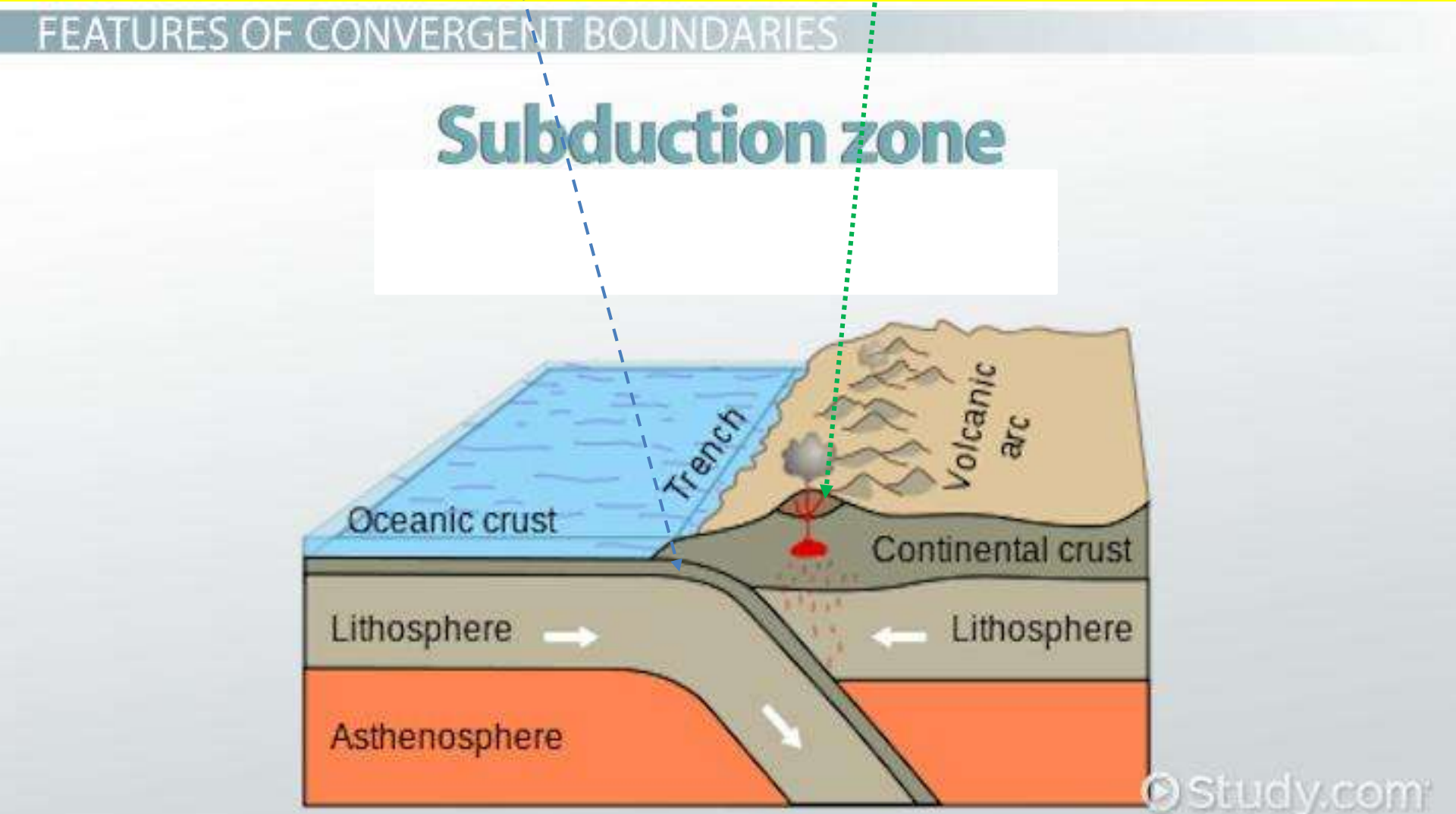


Aaah, well, Ok, Richard,
but I thought mountains were formed from volcanoes.

Let's look at a type of mountains called:

STRATOVOLCANIC MOUNTAINS

which develop as a result of the ***subduction*** *of an OCEANIC tectonic plate* at ***CON****VERGENT* BOUNDRIES.



Stratovolcanoes are big, tall mountains. Here, for example is Mt. Hood in Oregon. This mountain is an example of a Stratovolcano (mountain).



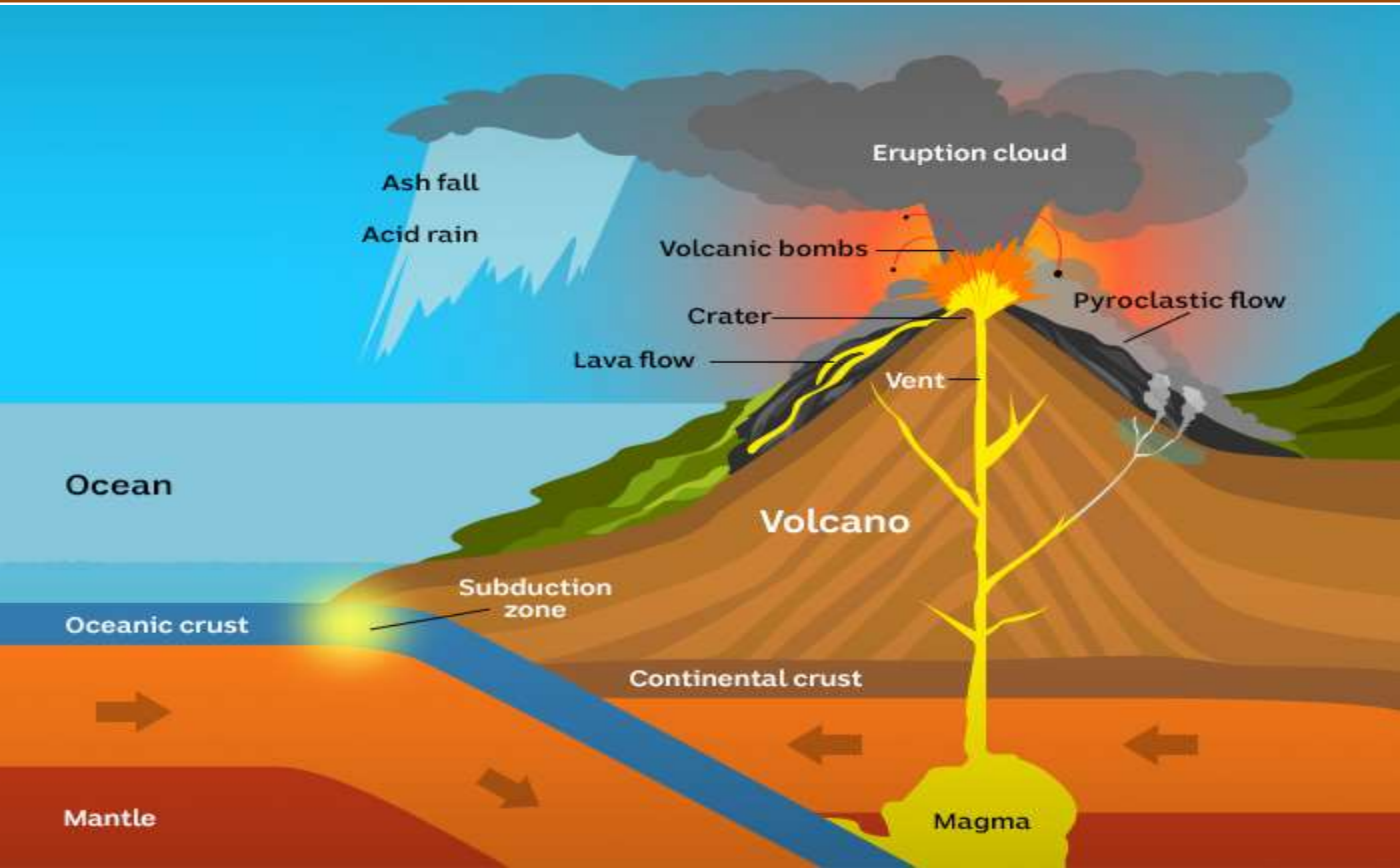
Here is a photo of Glacier Peak , one of the five major stratovolcanoes of the Cascade Volcanic Arc in the state of Washington.



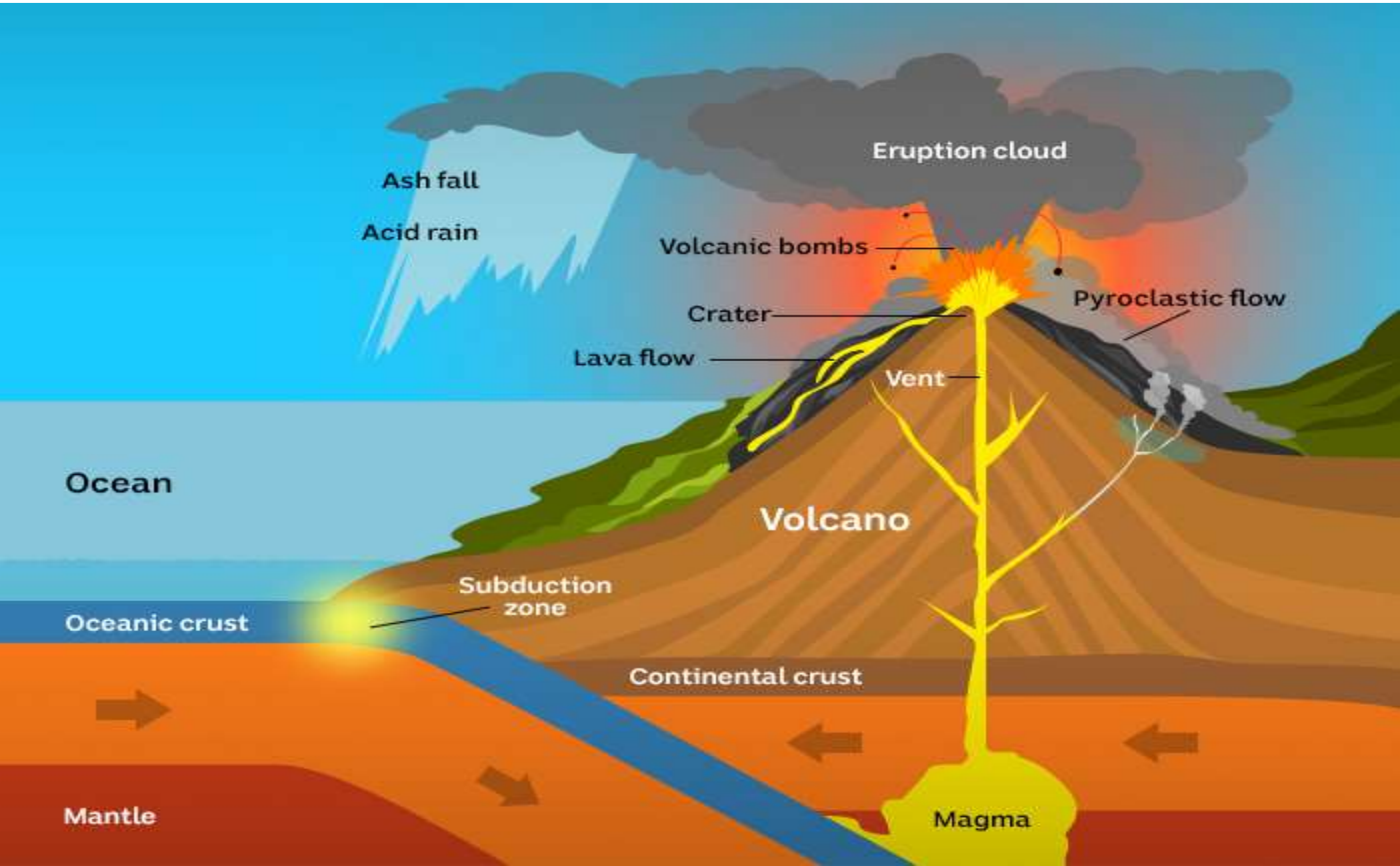
This image, which we saw last week, shows an area where ***stratovolcanoes***, in this case the **CASCADE MOUNTAINS** (including Mt. St Helens) along the western edge of the United states, are being formed **via subduction**.



When the oceanic tectonic plate subducts a Continental Plate, the subducted mater eventually melt to become magma, molten rock.



Magma, molten rock, moves up the shaft, where it is blasted out of the crater at the top of the shaft. . The lava blown out falls on the top and runs down the sides of the volcano, making it higher/larger.



A photo of still another stratovolcano, Lanin, in Patagonia.

(The southern part of the Andes Mountains)



Mount Shishildin, on Unimak Island is still another stratovolcano. It is found in the Aleutian Islands Range in southwest Alaska.

In this case the Pacific tectonic plate **subducted the North American tectonic plate to form this , and 11 more on this island.**



Mt. St. Helens is another typical stratovolcano. It is located in the Cascade Mountain Range in Washington.

This stratovolcano has not erupted for over 100 years.

Let's look at a couple of photos of Mt. St. Helens.

Certainly after seeing these photos you would never think that It would ever erupt again.

(Would you?)

Here is a photo of Mt. Saint Helens, another typical stratovolcano, Early Spring, 1980



Campers at Spirit Lake, early spring, 1980



3:47 minute animation of the explosion of Mt. St. Helens

https://www.youtube.com/watch?v=AYla6q3is6w



Mt. St. Helens today. 1300 feet has been blasted from the top . A large gap is now present in its side.



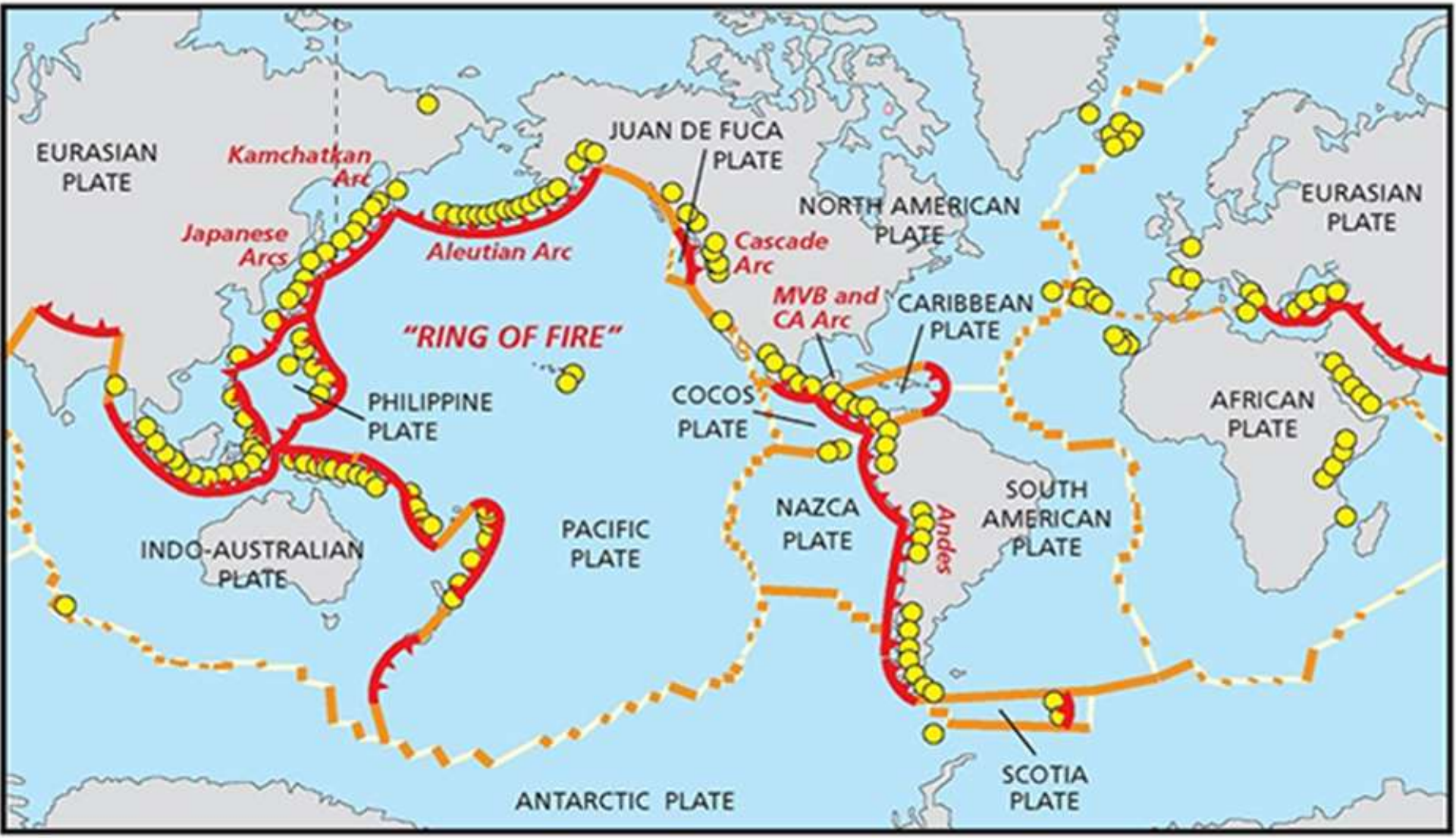
We cannot predict when a stratovolcano, like Mt. Fuji, will erupt!



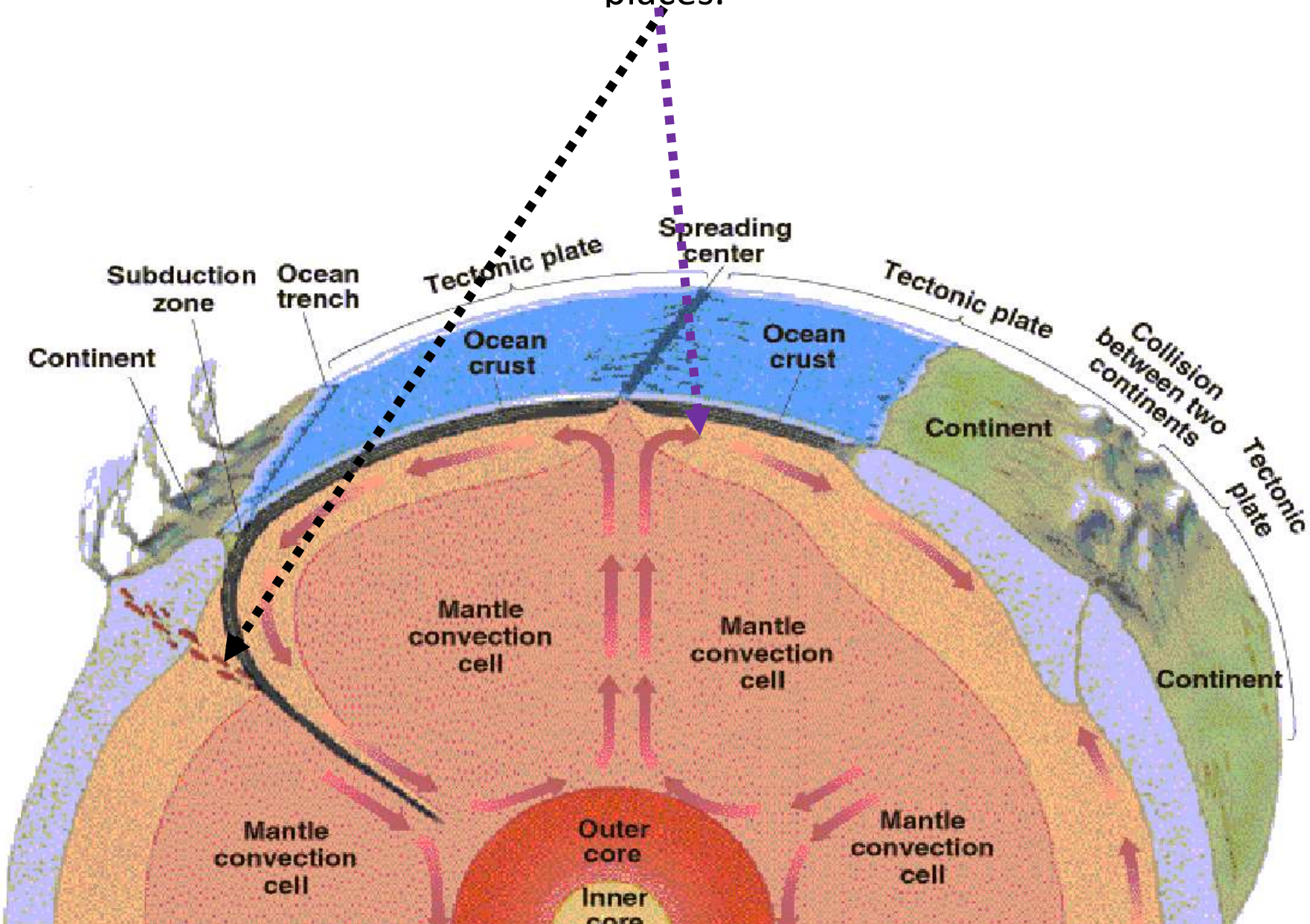
The RED smooth lines represent the areas where these ***Oceanic tectonic Plates*** are ***subducting Continental Tectonic Plates***.

{And where most of **the mountains we call stratovolcanoes** are formed}

The yellow circles represent either stratovolcanoes or shield volcanoes)



We have already pointed out that magma/lava comes from two different places.



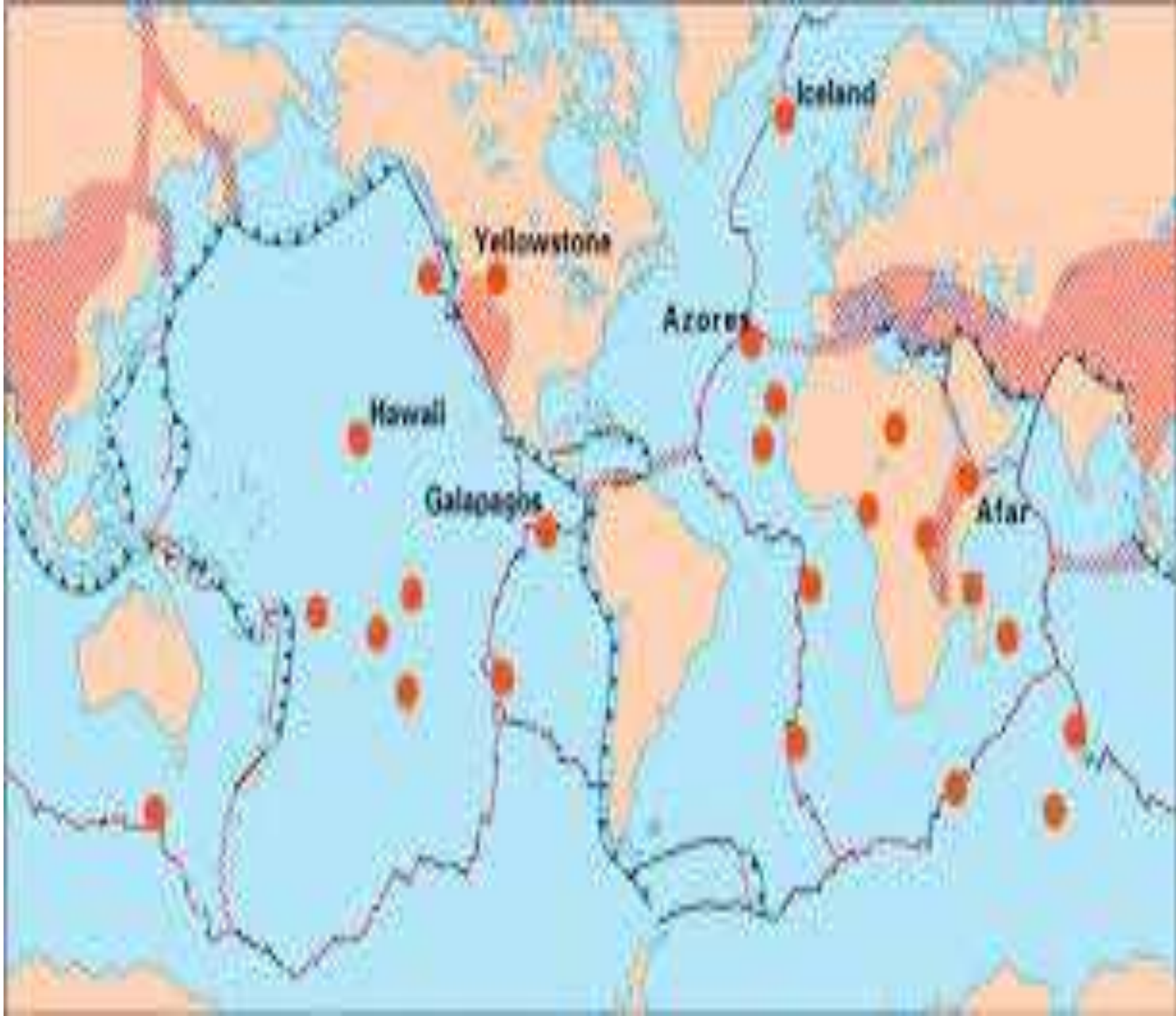
For example, in Hawaii, the magma begins at the ASTHENOSPHERE.

From the Asthenosphere it can come up through holes in the crust of the earth.

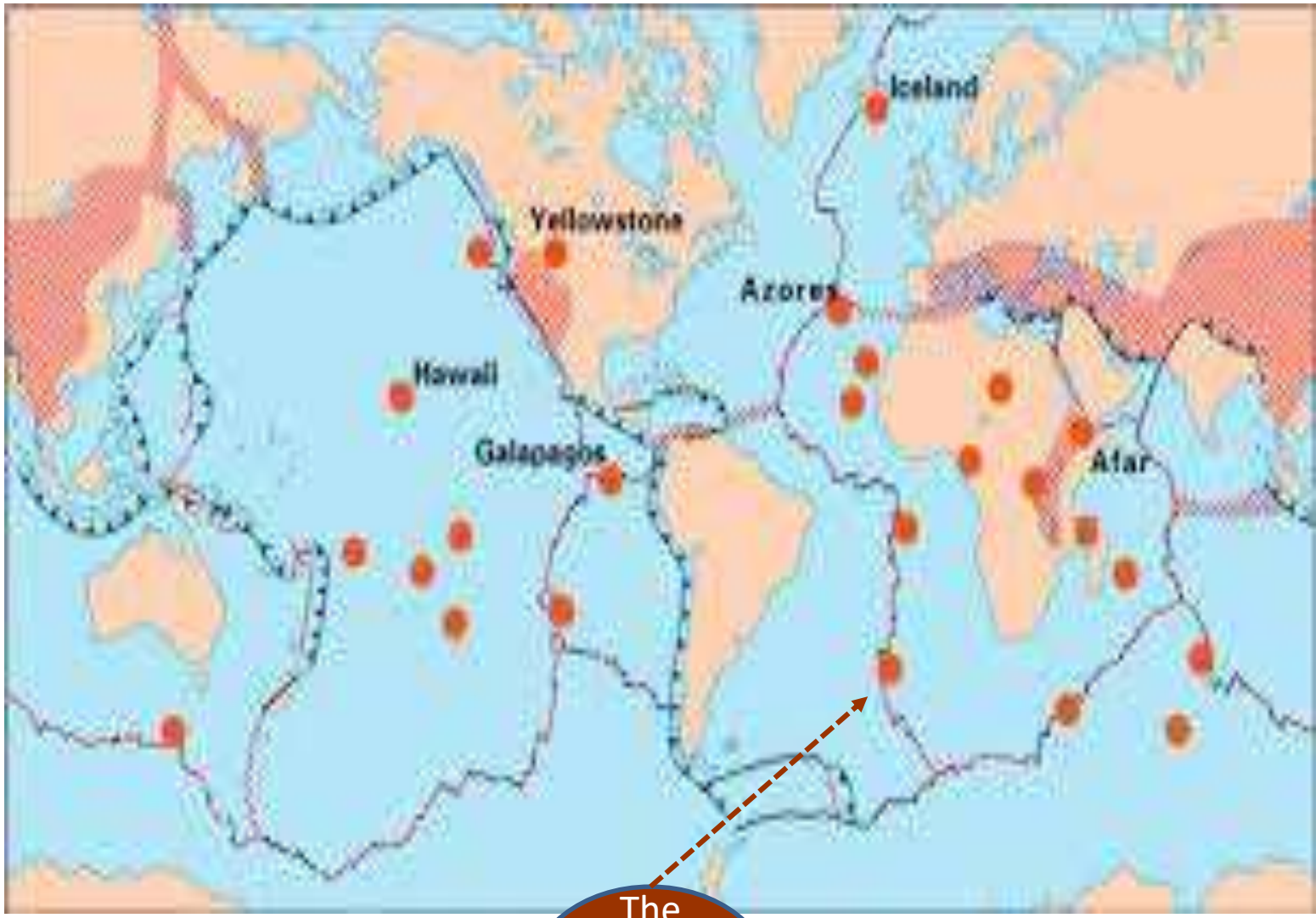
Sometimes the earth is pulled apart, and the crust cracks open, leaving a gap, through which the magma from the Asthenosphere can come up.

This image shows some of the earth's ***HOT SPOTS***.

Hot spots are areas/places where mountains are formed from lava coming up ***from a hole in the crust of the earth***



For example, ***MOUNTAINS*** (which some people call islands) like: Hawaii, The Azores, The Galapagos Islands, The Island of St. Helena, - - - were all formed when lava erupted through a hole in the crust of the earth.



Sometimes tectonic plates which are next to each other

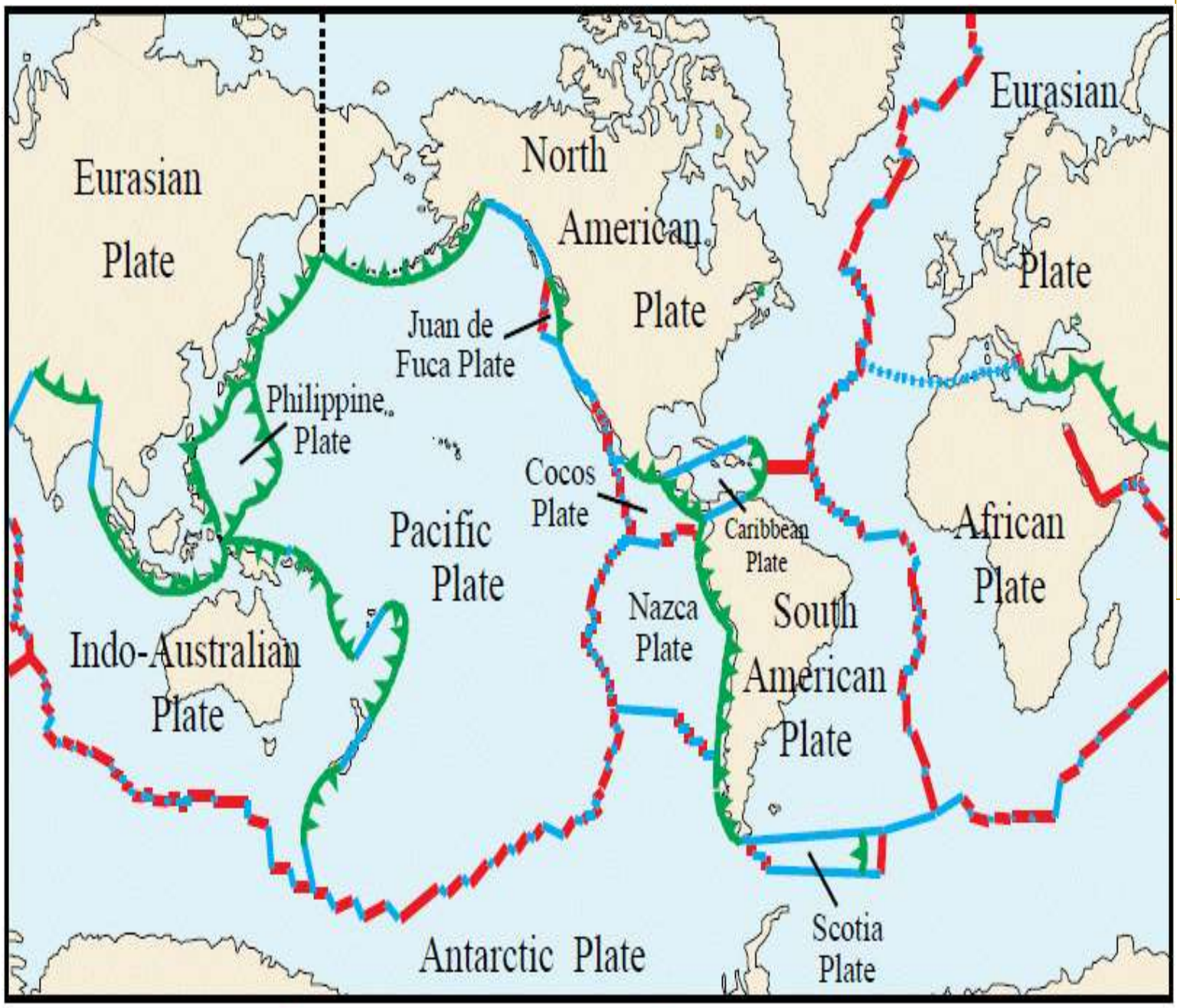
are pulled apart

(DIVERGE)

from each other.

At some places the DIVERGENT TECTONIC PLATES are on land;

At some places the DIVERGING TECTONIC PLATES are on the bottom of the ocean.

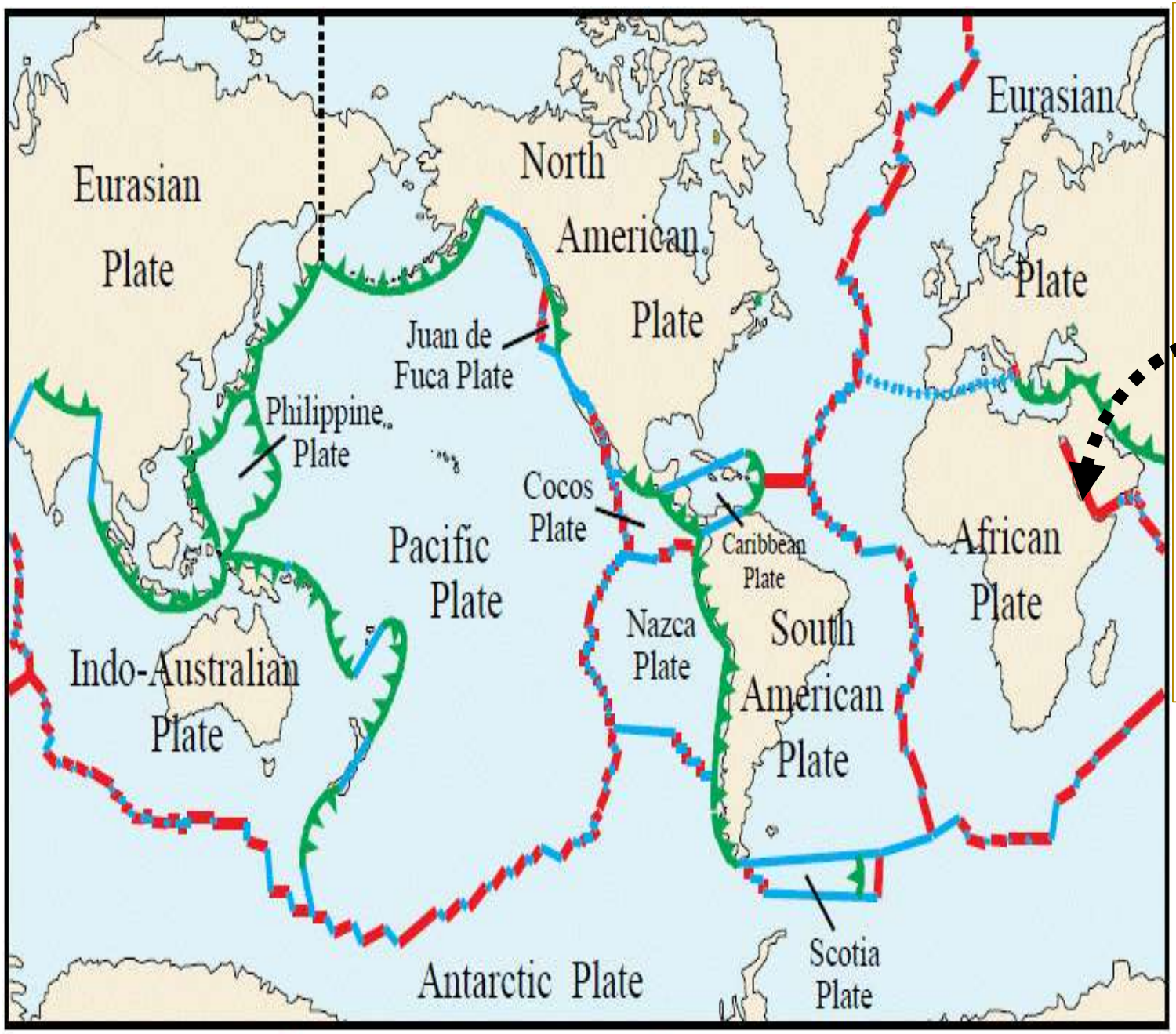


RED/BLUE lines

=

DIVERGING TECTONIC PLATE BOUNDRIES

.



(Note the location of the **GREAT AFRICAN RIFT**, in North East Africa where the African Plate is **DIVERGING**.

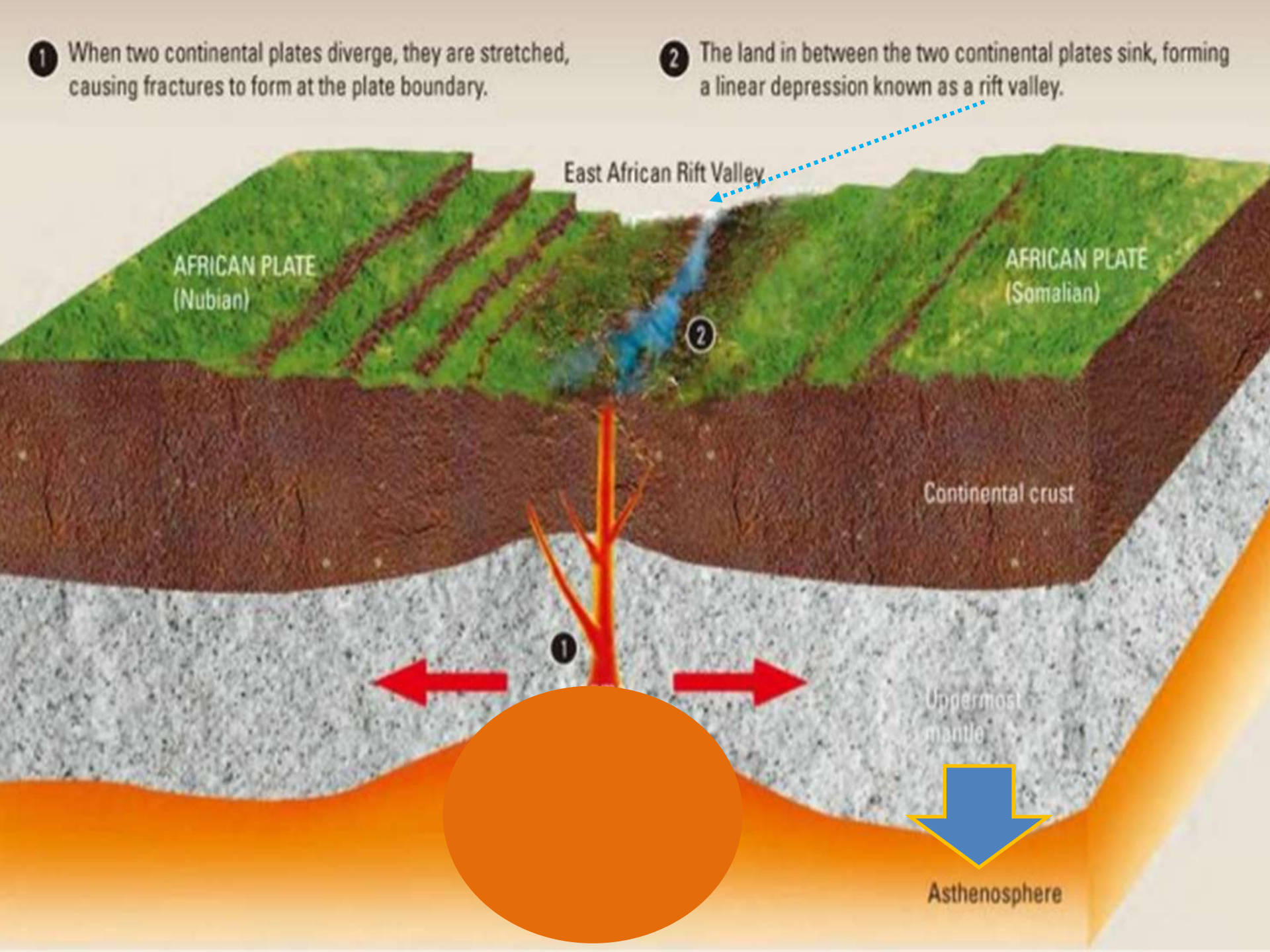
An example of continental tectonic plates diverging *on land*, and forming mountains there, is

THE GREAT AFRICAN RIFT

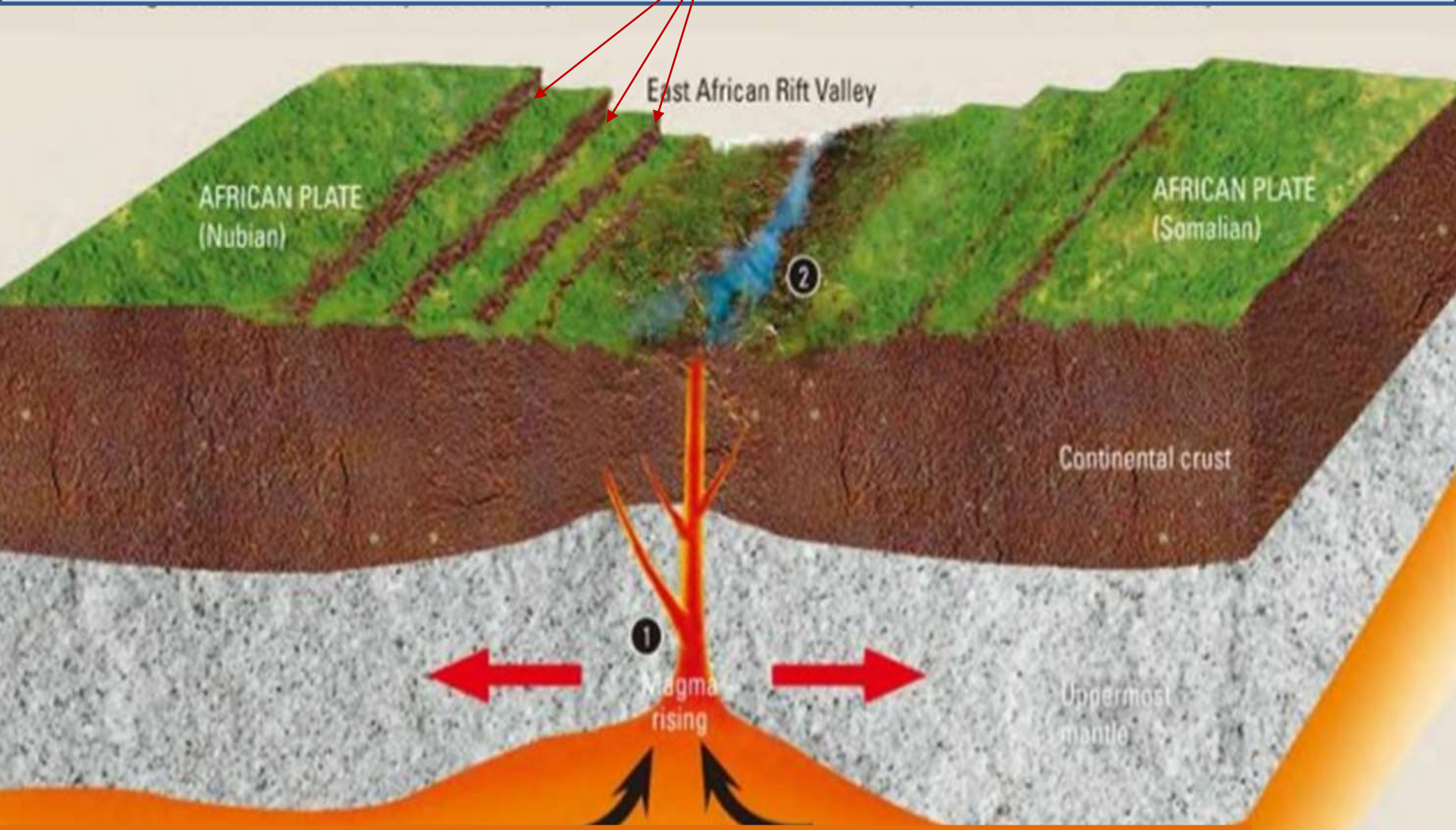
in North East Africa.

In a RIFT SYSTEM *part of the earth sinks as the divergent tectonic plates move apart.*
The land is stretched, and becomes a Basin and Range/Fault-Block mountain ranges. (like we saw in Nevada).

The original plateau remains high, and in effect becomes a mountain.
As the plate is stretched, FAULT-BLOCK (Basin and range) mountains & Valleys are formed.

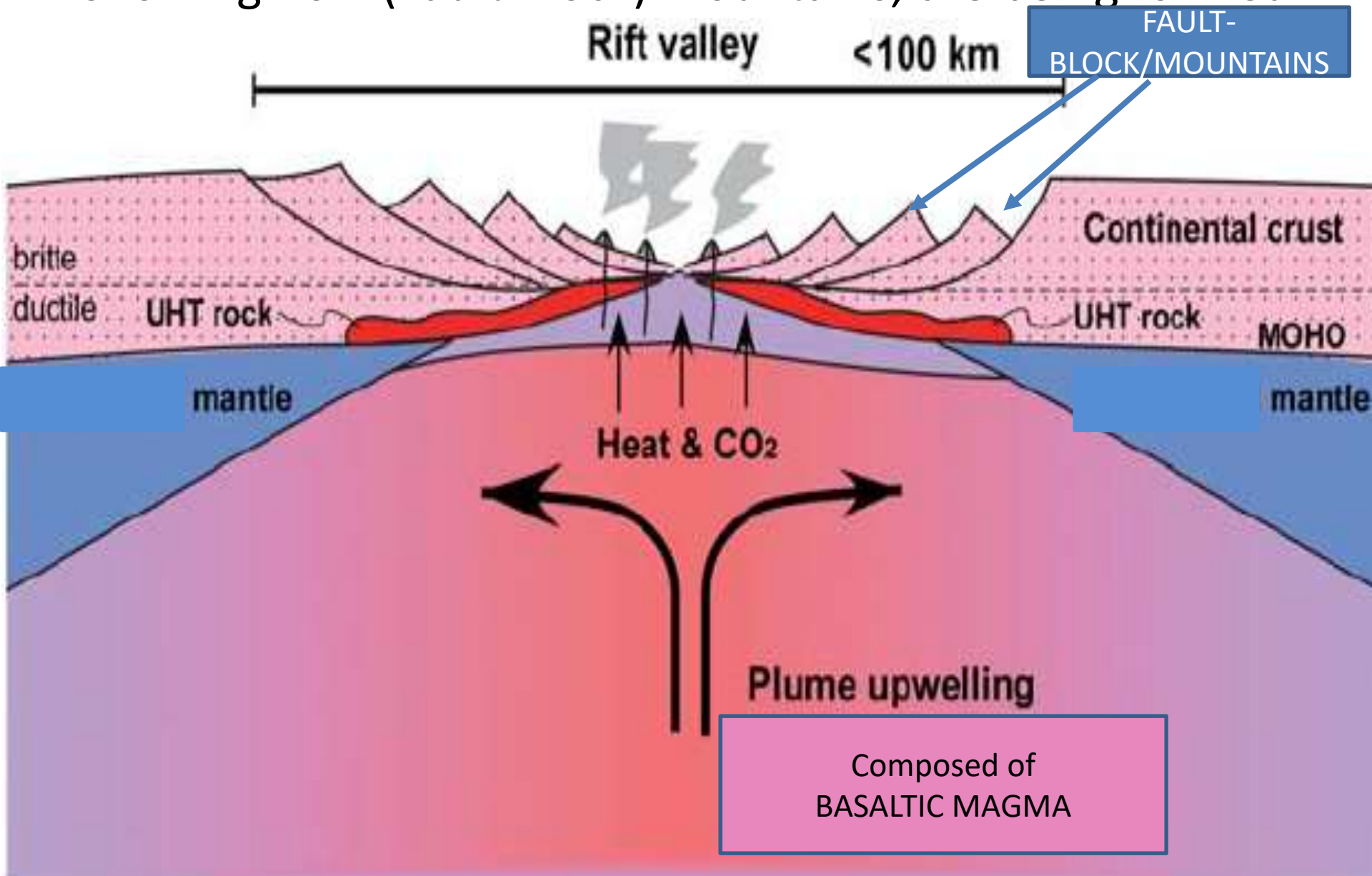

1 When two continental plates diverge, they are stretched, causing fractures to form at the plate boundary.
2 The land in between the two continental plates sink, forming a linear depression known as a rift valley.
East African Rift Valley
AFRICAN PLATE (Nubian)
AFRICAN PLATE (Somalian)
2
Continental crust
1
Uppermost mantle
Asthenosphere

Faults/ Fault-Block Mountains

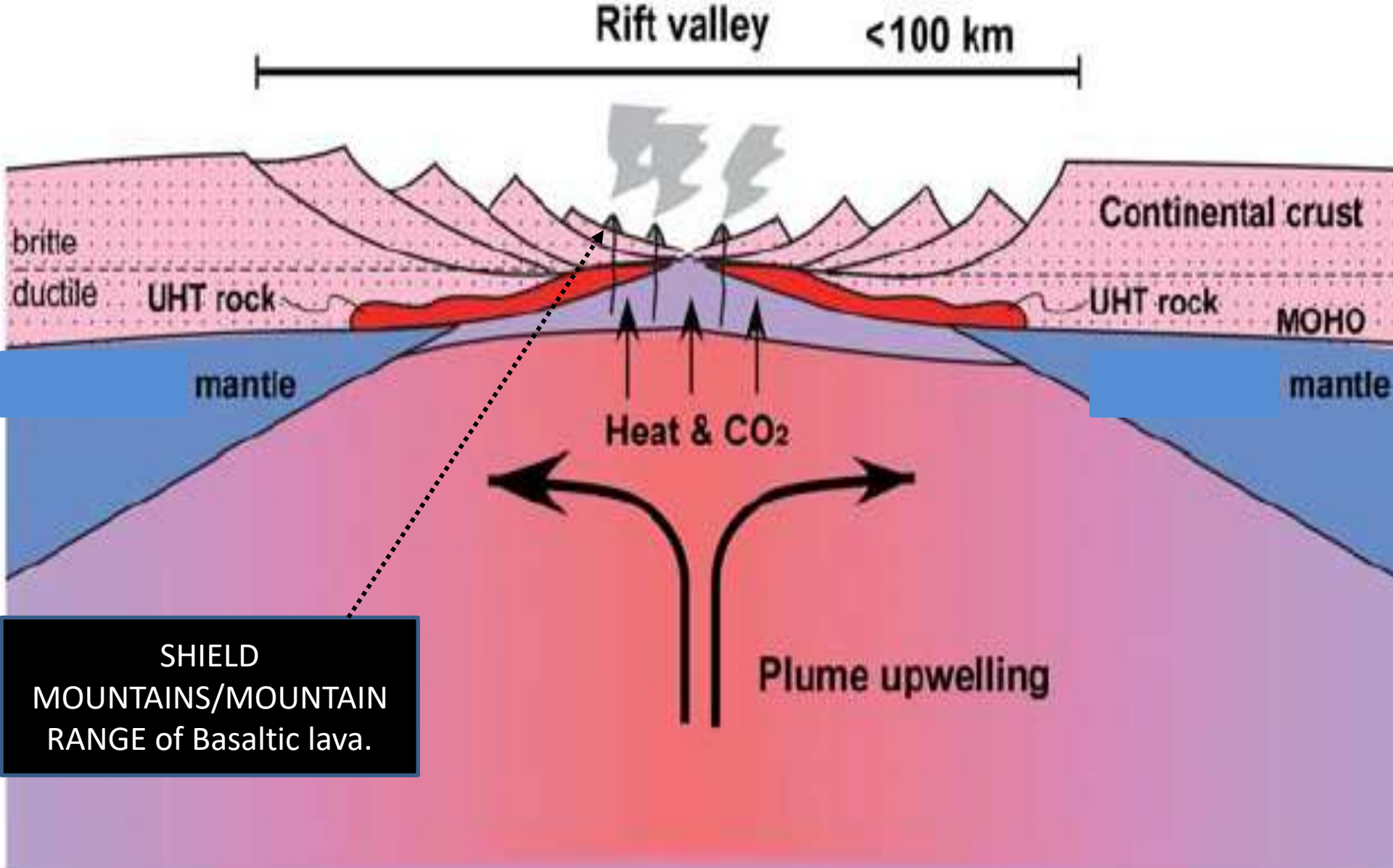


Also when the plates DIVERGE basaltic magma comes up between the space between the diverging plates. These can form SHIELD VOLCANOES or A MOUNTAIN RANGE.

Another image of the GREAT AFRICAN RIFT system , showing how (Fault Block) mountains, are being formed



Another image of the GREAT AFRICAN RIFT system , showing SHIELD MOUNTAINS, an edge of a MOUNTAIN RANGE.



Speaking of

THE GREAT RIFT VALLEY

in Africa

If the diverging/rifting tectonic plates are “on” land, they are called:

CONTINENTAL RIFT SYSTEMS.

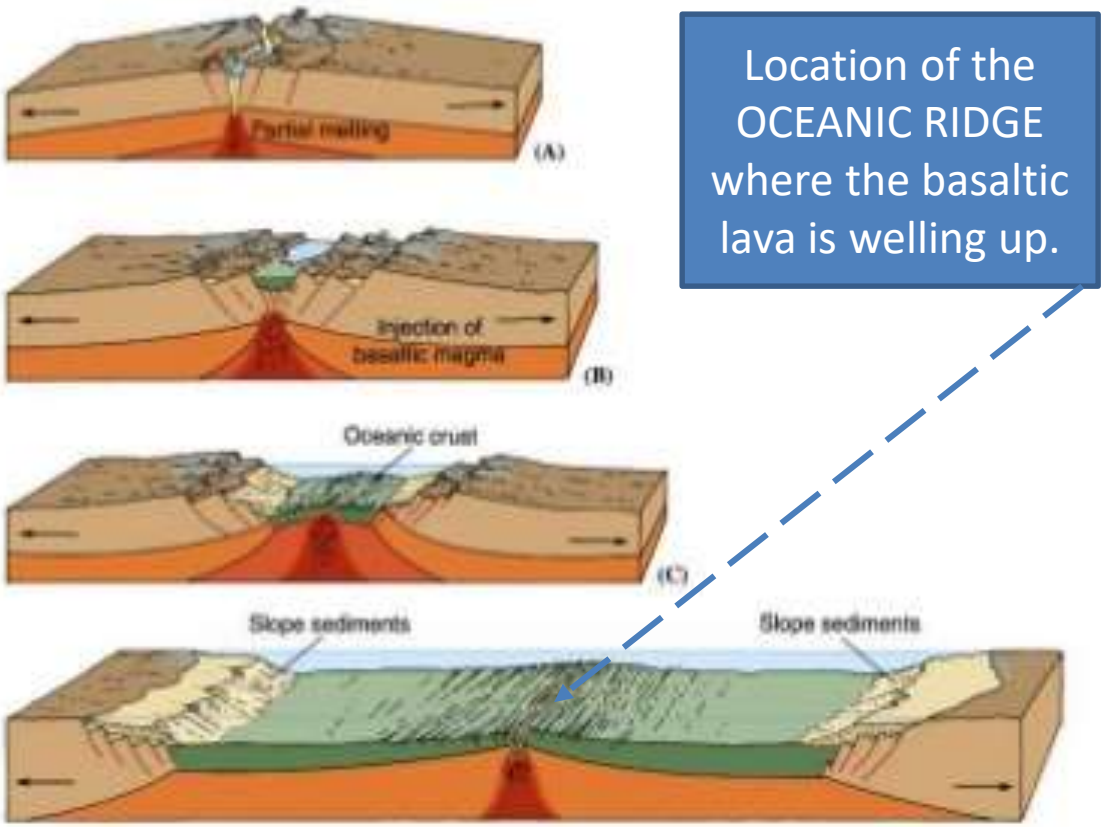
This image shows the Location of part of the 3700 mile long

AFRICAN RIFT VALLEY



The East Afican Rift Valleys

Continental Rift Systems



Location of the OCEANIC RIDGE where the basaltic lava is welling up.

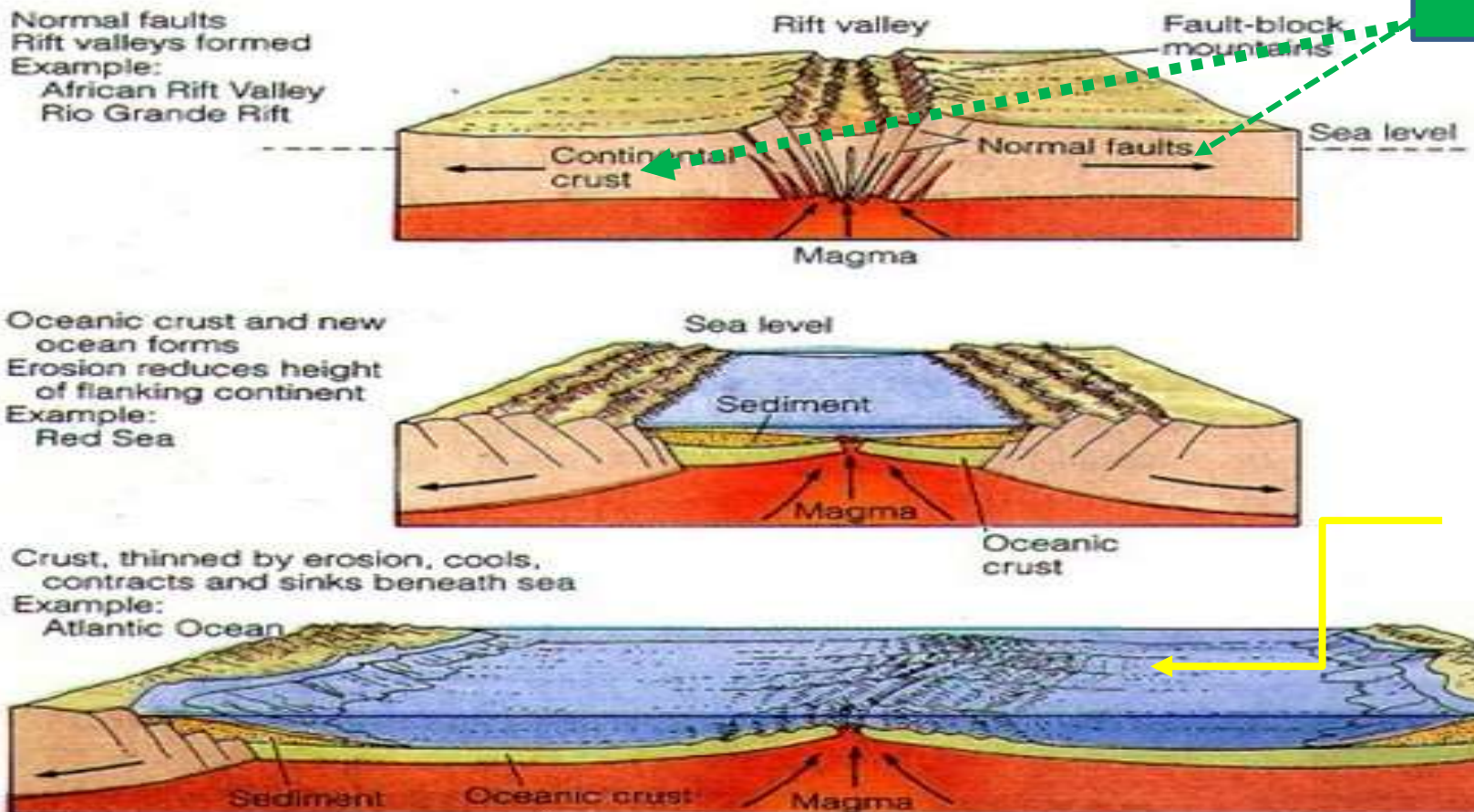


As continental crust is stretched, it becomes thinner and eventually produces an ocean basin. Rift systems are characterized by linear mountain ranges, shallow focus earthquakes, and basaltic volcanism. Over time, the rift system will evolve into an oceanic ridge.

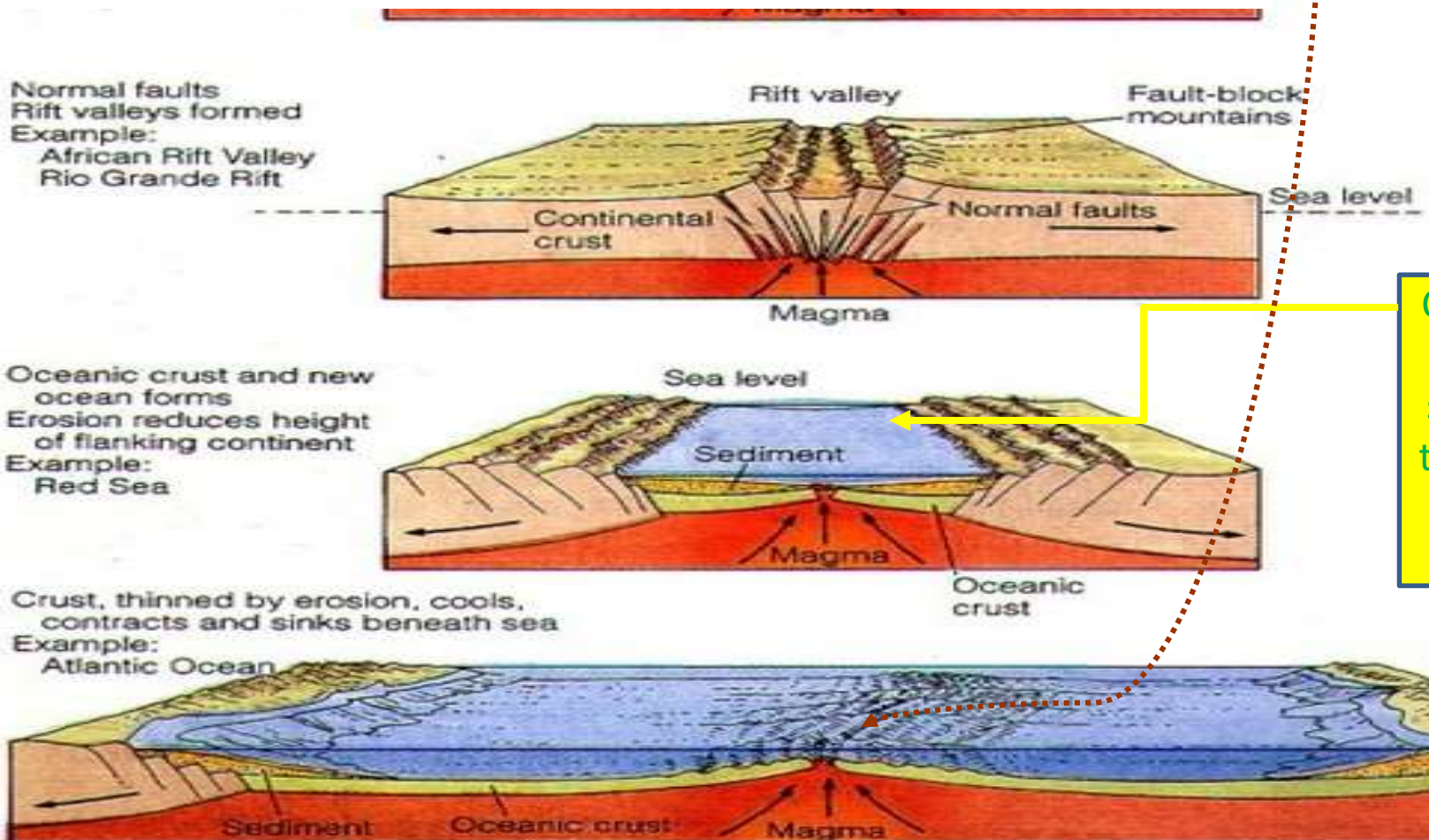
If the tectonic plates ***DIVERG***E on land,

→FAULT BLOCK MOUNTAINS will initially be formed.

The continental plate is stretching apart → FAULT BLOCK MOUNTAINS!



The diverging tectonic plates continue to move apart, allowing **water** to flow in at the ends. This fills the diverging space. Soon ***more basaltic lava*** erupts from between the diverging plates, forming ***<u>a linear mountain range OF BASALTIC LAVA</u>***, under the water.



Continuation of the spreading of the Diverging Tectonic plate

Here is an image of A SECTION OF THE GREAT RIFT VALLEY IN NORTH EAST AFRICA

Note the piles of basaltic lava and cinder cones.



Here is a photo of a cinder cone “mountain” photographed in ***Africa’s Rift Valley***.



Another view of some of the FAULT-BLOCK mountains (and valleys) of the Rift Valley in Africa.

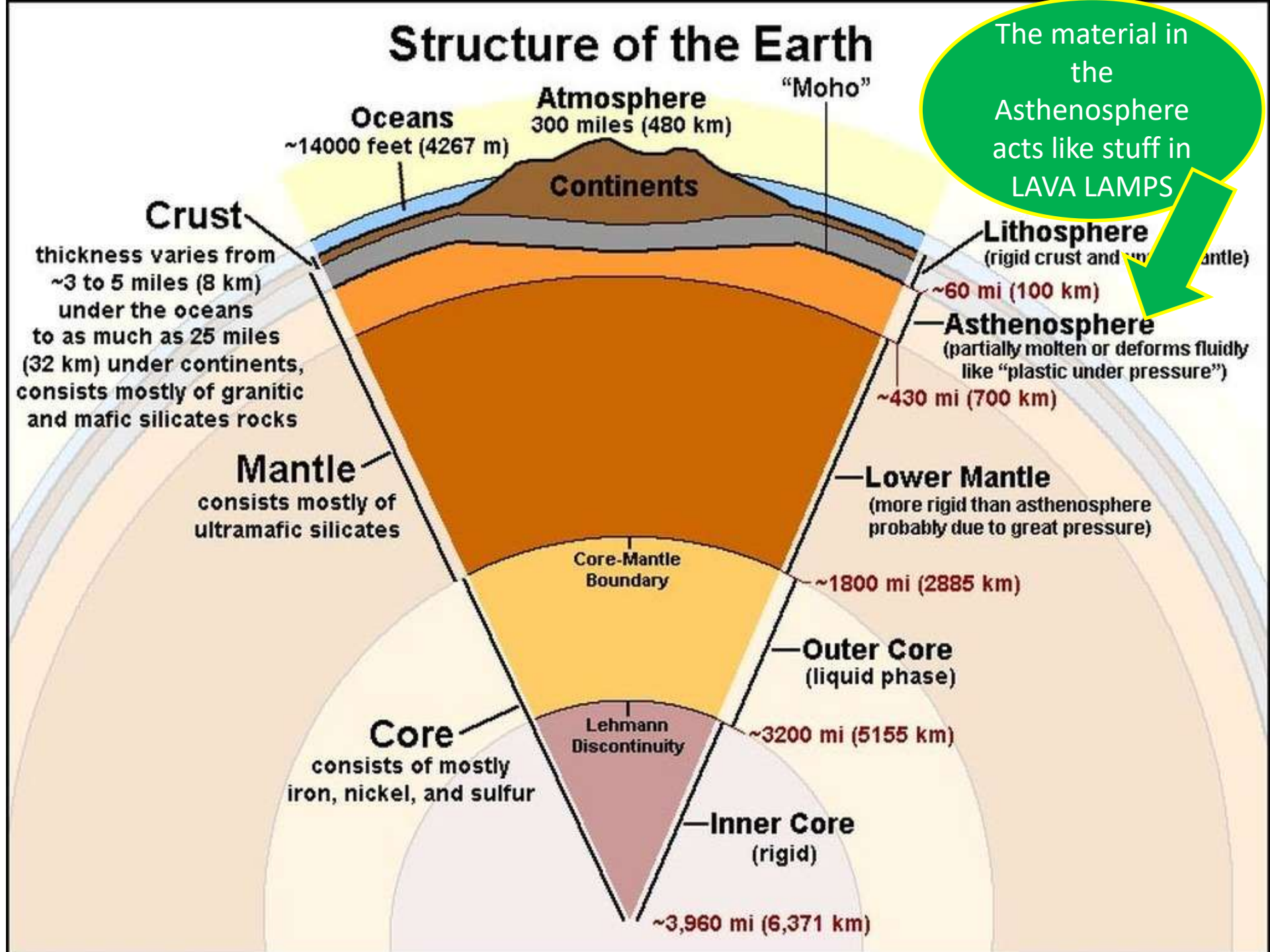


The Great African Rift will continue widening until we get

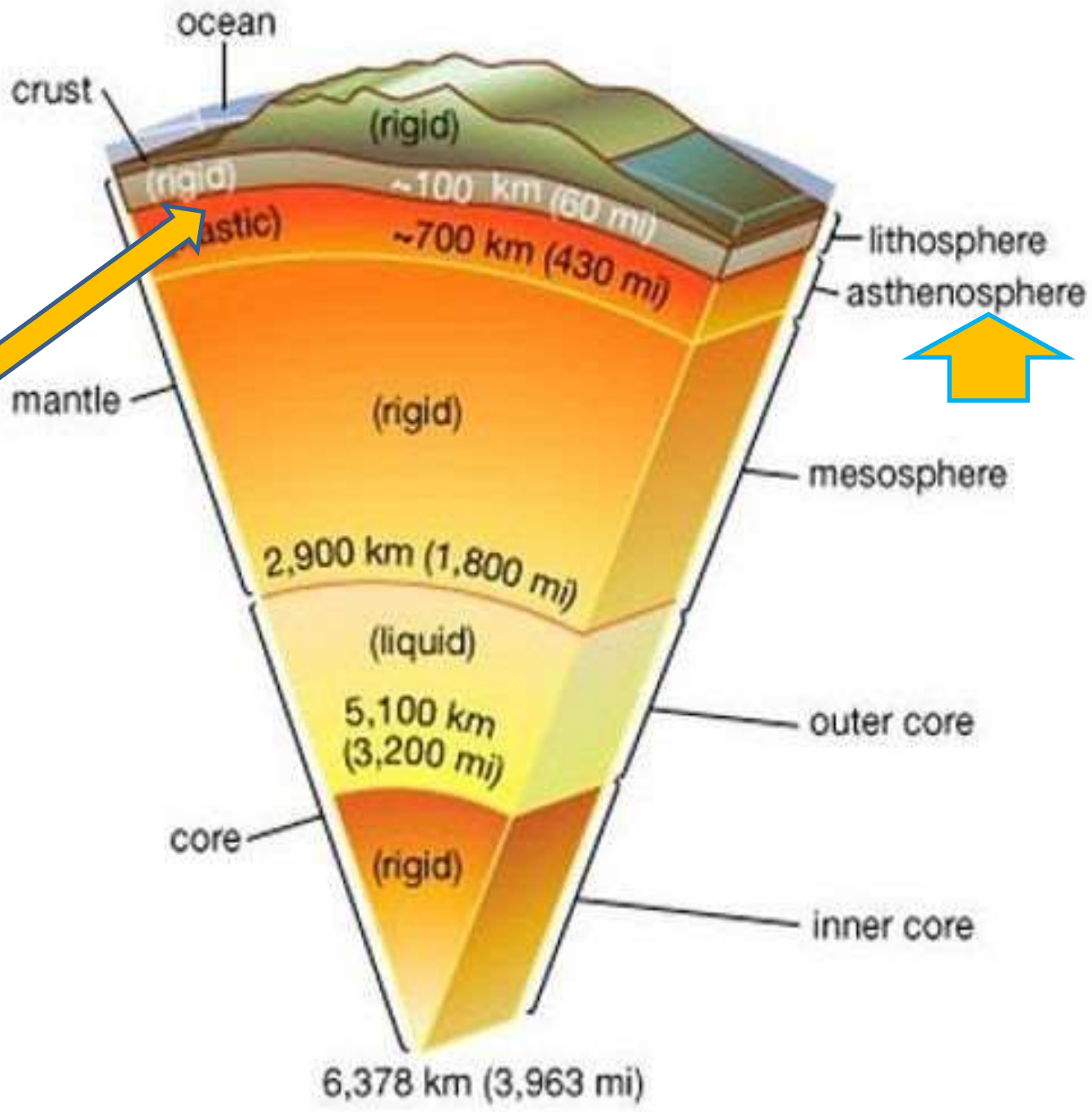


We have been talking about BASALTIC LAVA.

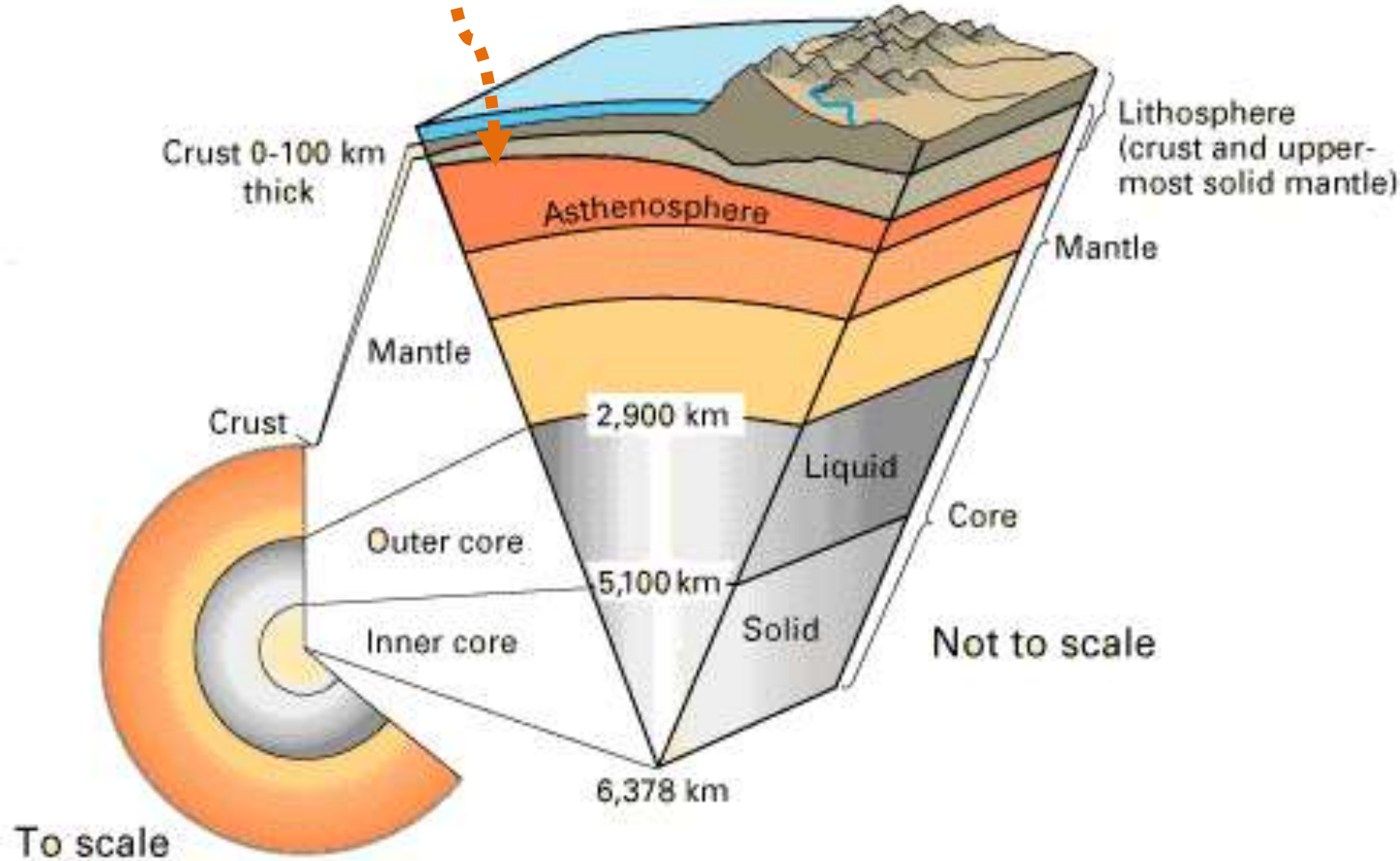
AS A REMINDER, LET'S AGAIN LOOK AT WHERE BASALTIC LAVA COME FROM.


Structure of the Earth
The material in the Asthenosphere acts like stuff in LAVA LAMPS
Atmosphere
300 miles (480 km)
"Moho"
Oceans
~14000 feet (4267 m)
Continents
Crust
thickness varies from ~3 to 5 miles (8 km) under the oceans to as much as 25 miles (32 km) under continents, consists mostly of granitic and mafic silicates rocks
Lithosphere
(rigid crust and
antle)
~60 mi (100 km)
Asthenosphere
(partially molten or deforms fluidly like "plastic under pressure")
~430 mi (700 km)
Mantle
consists mostly of ultramafic silicates
Lower Mantle
(more rigid than asthenosphere probably due to great pressure)
Core-Mantle Boundary
~1800 mi (2885 km)
Outer Core
(liquid phase)
Lehmann Discontinuity
~3200 mi (5155 km)
Core
consists of mostly iron, nickel, and sulfur
Inner Core
(rigid)
~3,960 mi (6,371 km)

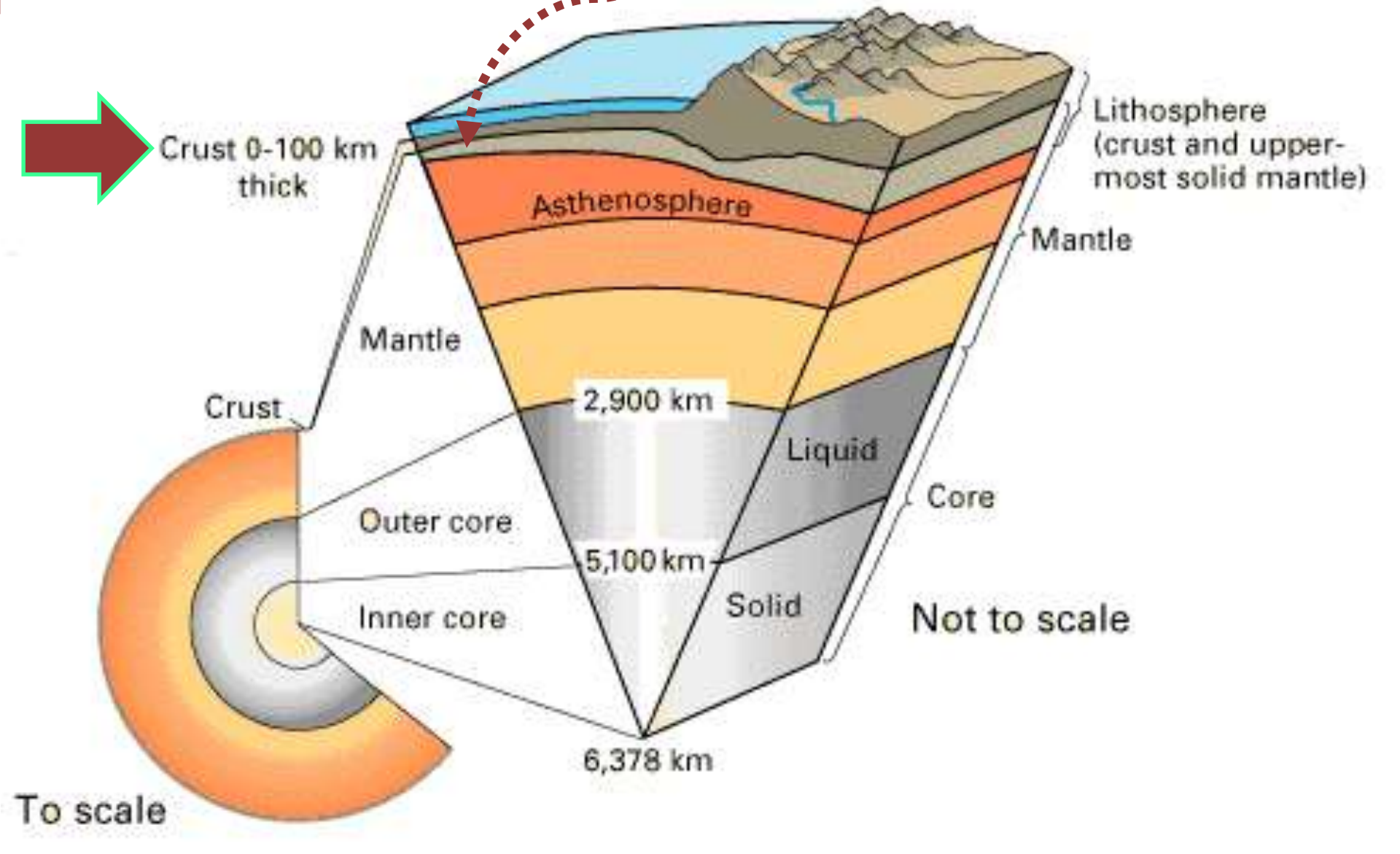
Here is the
ASTHENOSPHERE



Earth scientists discovered that ***the BASALTIC MAGMA*** at the ***<u>top</u> of the Asthenosphere was " liquid".***



*If the **CRUST & Lithosphere** gets a hole in them,*
this basaltic magma will flow up through these openings
*→ **SHIELD VOLCANO/MOUNTAIN RANGE.***



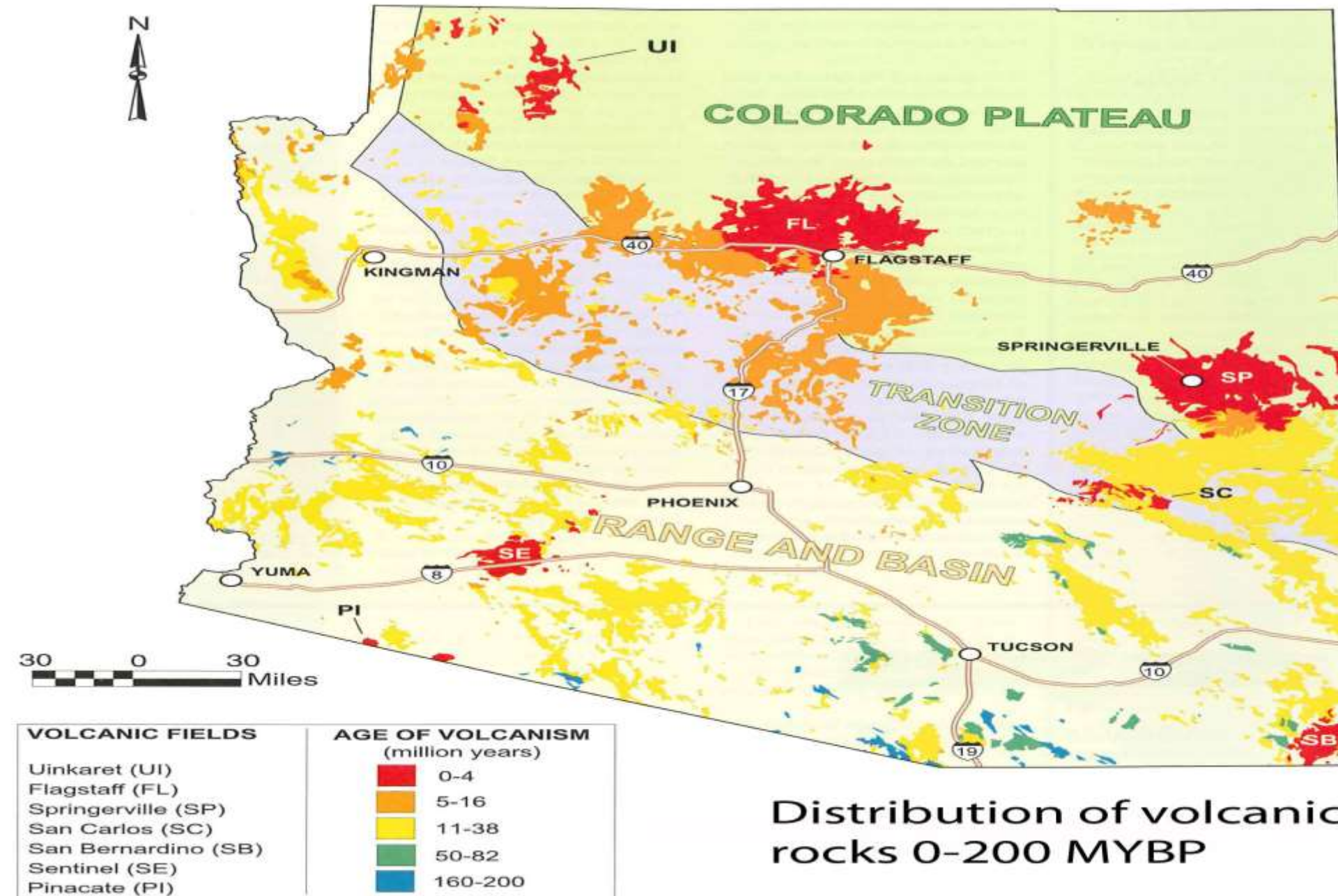
Here is a photo of ***Basaltic lava, which began its upward course beginning at the Asthenosphere, flowing through a hole in the crust, as it*** erupts out of a “small” opening. Some of the lava hardens at the rim of the opening, but most of the lava runs down the sides of the cone, making the base of the cone wider → **cinder cone.**

Fagradalsfjall volcano (Reykjanes Peninsula, Iceland



There were many eruptions of basaltic lava→ shield volcano formation/cinder cones.

For example, here **in** *Arizona*.



Distribution of volcanic rocks 0-200 MYBP

An example is Sunset Crater Volcano, a SHIELD VOLCANO, ~ 8,000 feet high in **Arizona**.. ... Sunset Crater Volcano erupted over 900 years ago, making it the youngest **cinder cone in a field of over 600 shield/cinder cone volcanoes there**...



Another view of Sunset Crater- cinder- cone- Volcano (mountain) showing its shape as an (upside down) cone, as well as its crater. It is located 25 miles north of Flagstaff,



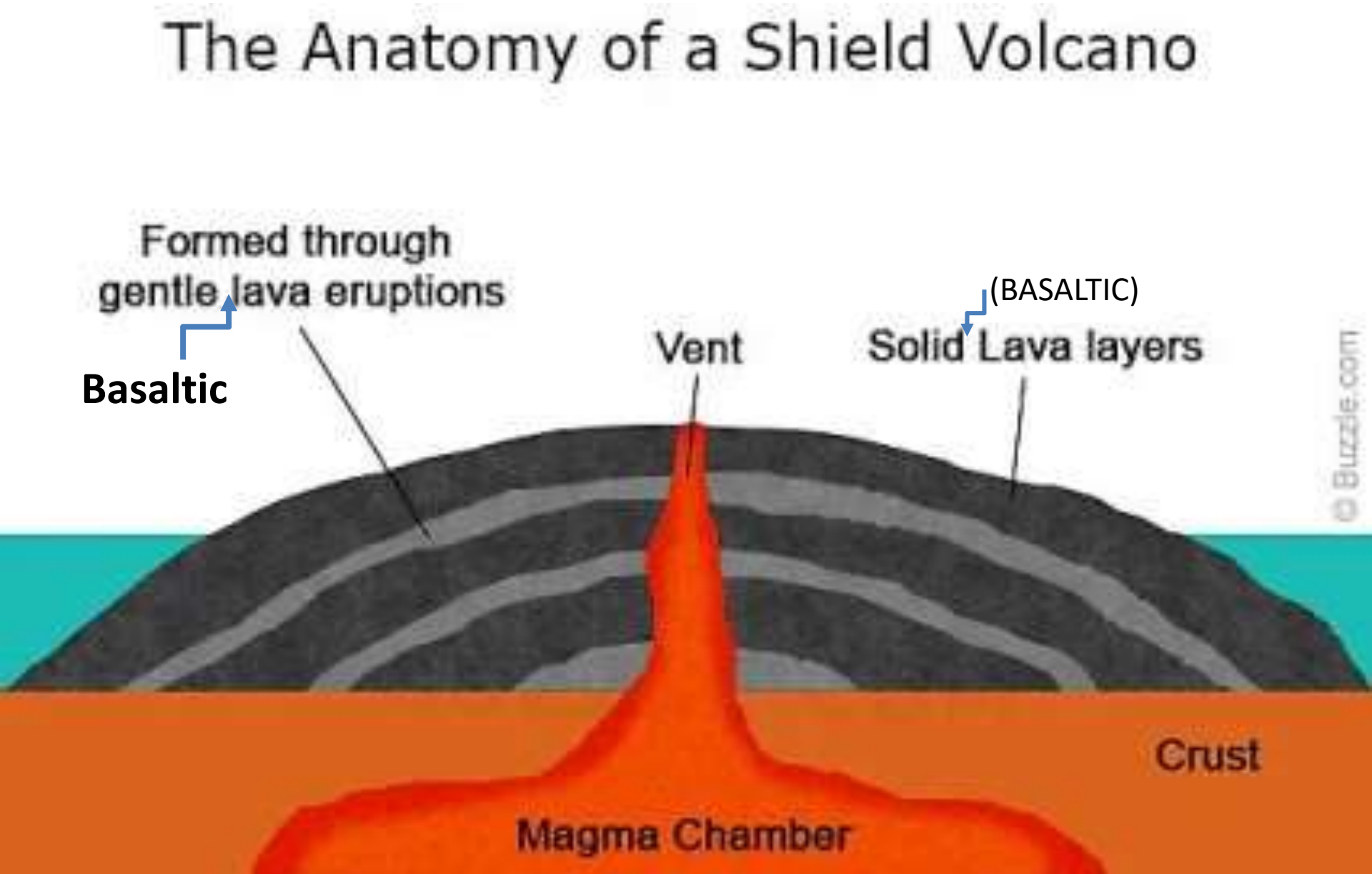
A photo of **Lava Butte**

→ a cinder cone Mountain in central Oregon. The cinder cone too is capped by a crater which extends about 60 feet deep. Not all cinder cone mountains exhibit craters.



A view of the INSIDES of a shield/Cinder Cone/ volcano/mountain.

The magma/lava of shield volcanoes is BASALTIC.



Rifts exist in different parts of the world. For example , the city of Albuquerque sits in the middle of the RIO GRANDS VALLEY rift.

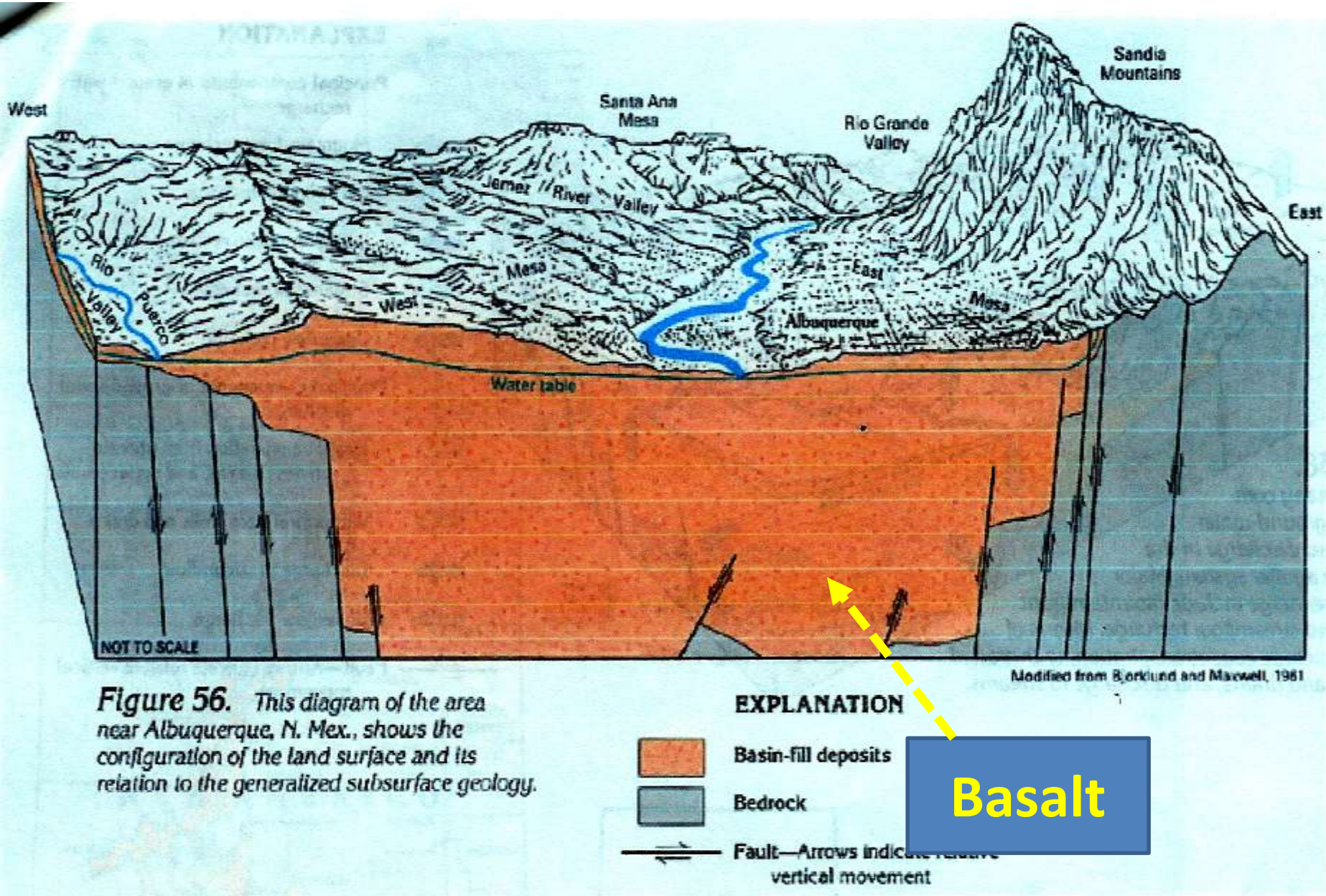
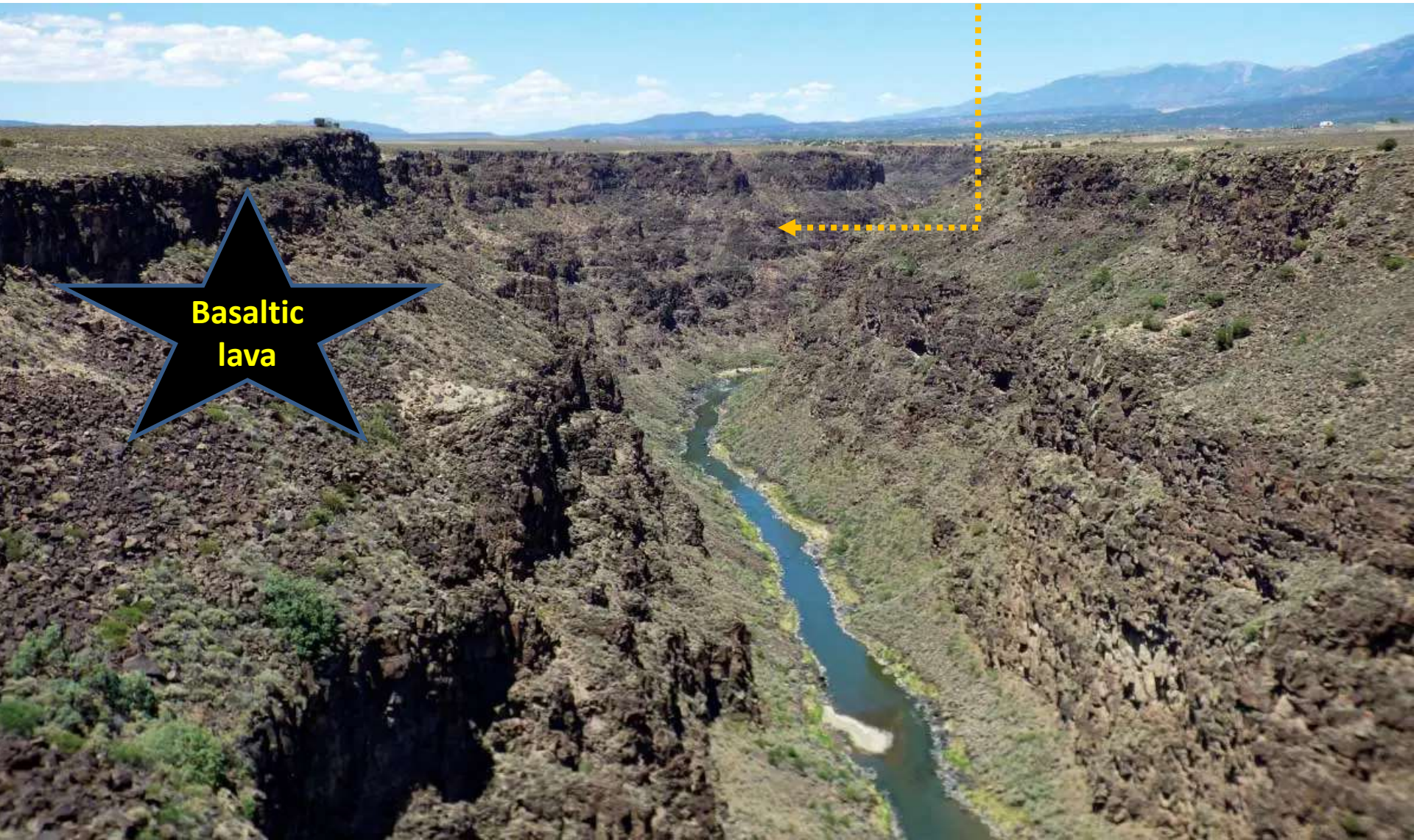


Figure 56. *This diagram of the area near Albuquerque, N. Mex., shows the configuration of the land surface and its relation to the generalized subsurface geology.*

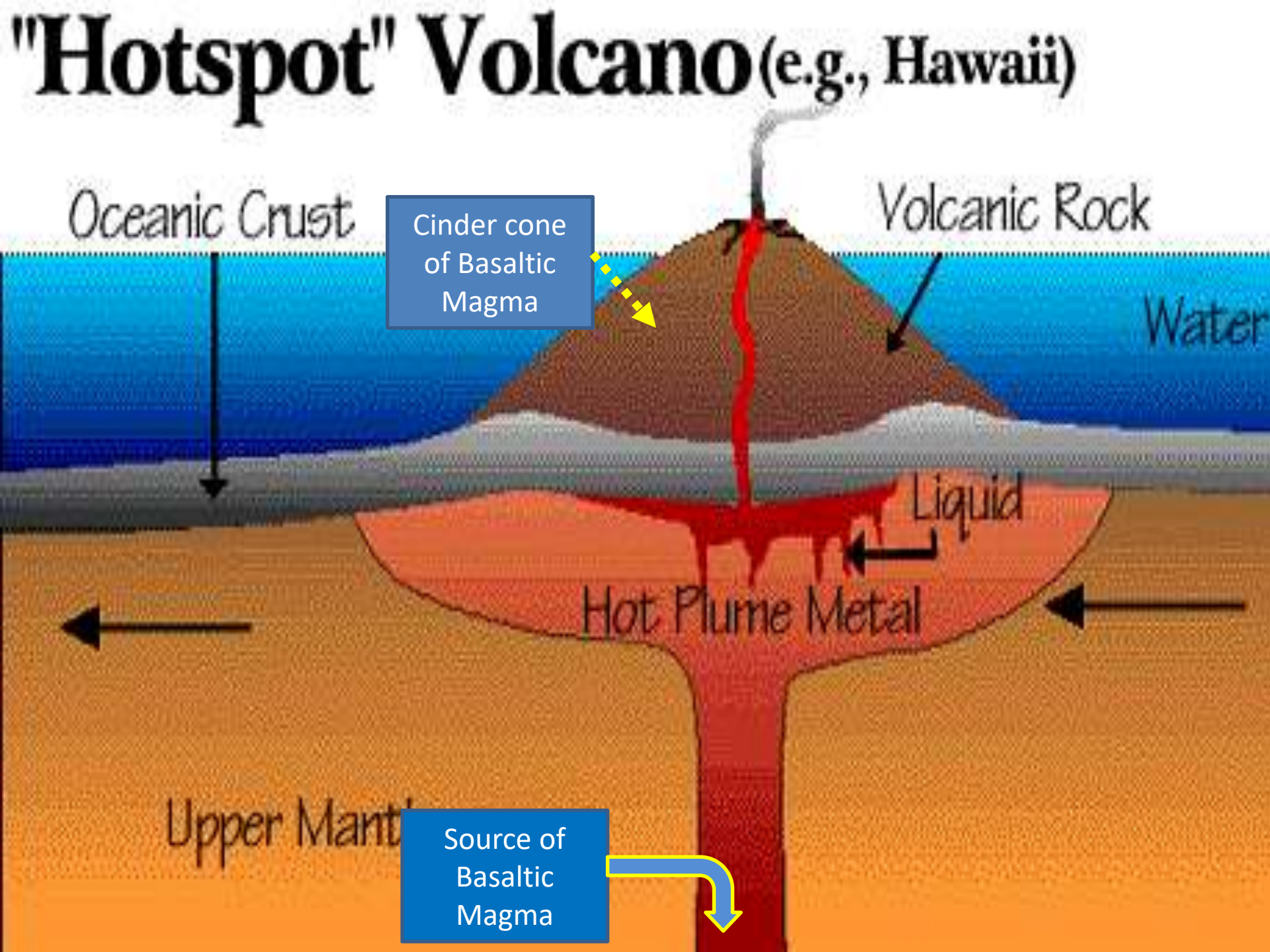
In some areas, instead of the magma erupting from a “hole”, the earth “RIFTS”/DIVERGES. The result can be a big valley, whose sides are composed of the Basaltic Lava that has spewed up, then hardened.. An example of this is the RIO GRANDE VALLEY RIFT, seen below in New Mexico.

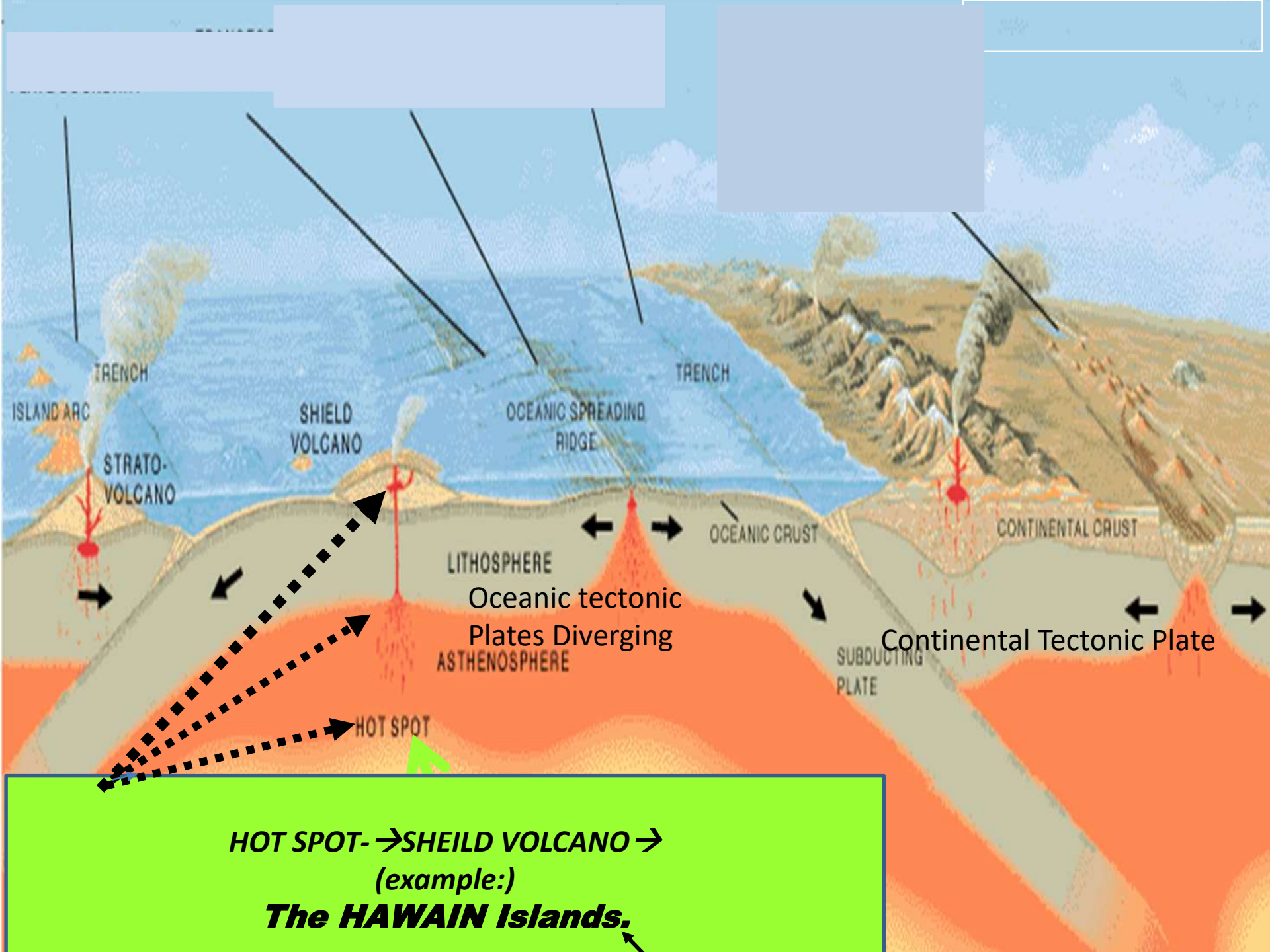


Want to look at ***SHIELD VOLCANOES***/mountains again? Maybe some **BIG ones!?**
They are like **HOT SPOT** volcanoes/mountains. Hot Spot volcanoes start out as

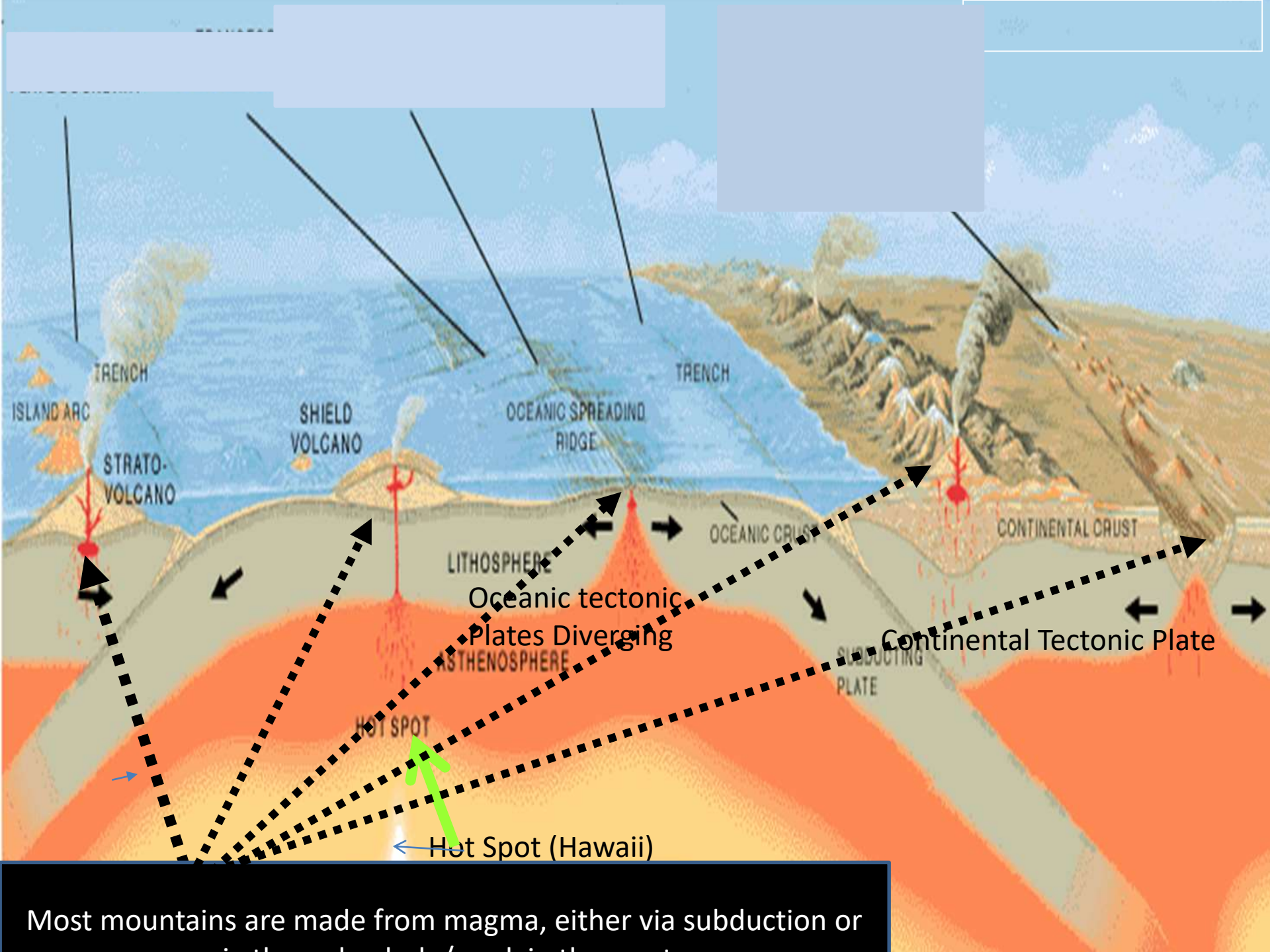
SHIELD VOLCANOES




"Hotspot" Volcano (e.g., Hawaii)
Oceanic Crust
Cinder cone of Basaltic Magma
Volcanic Rock
Water
Liquid
Hot Plume Metal
Upper Mant
Source of Basaltic Magma



HOT SPOT-→SHEILD VOLCANO→
(example:)
The HAWAIN Islands.



Most mountains are made from magma, either via subduction or

Who has seen Diamond Head, *the top of a very high mountain? (& an old shield volcano)*



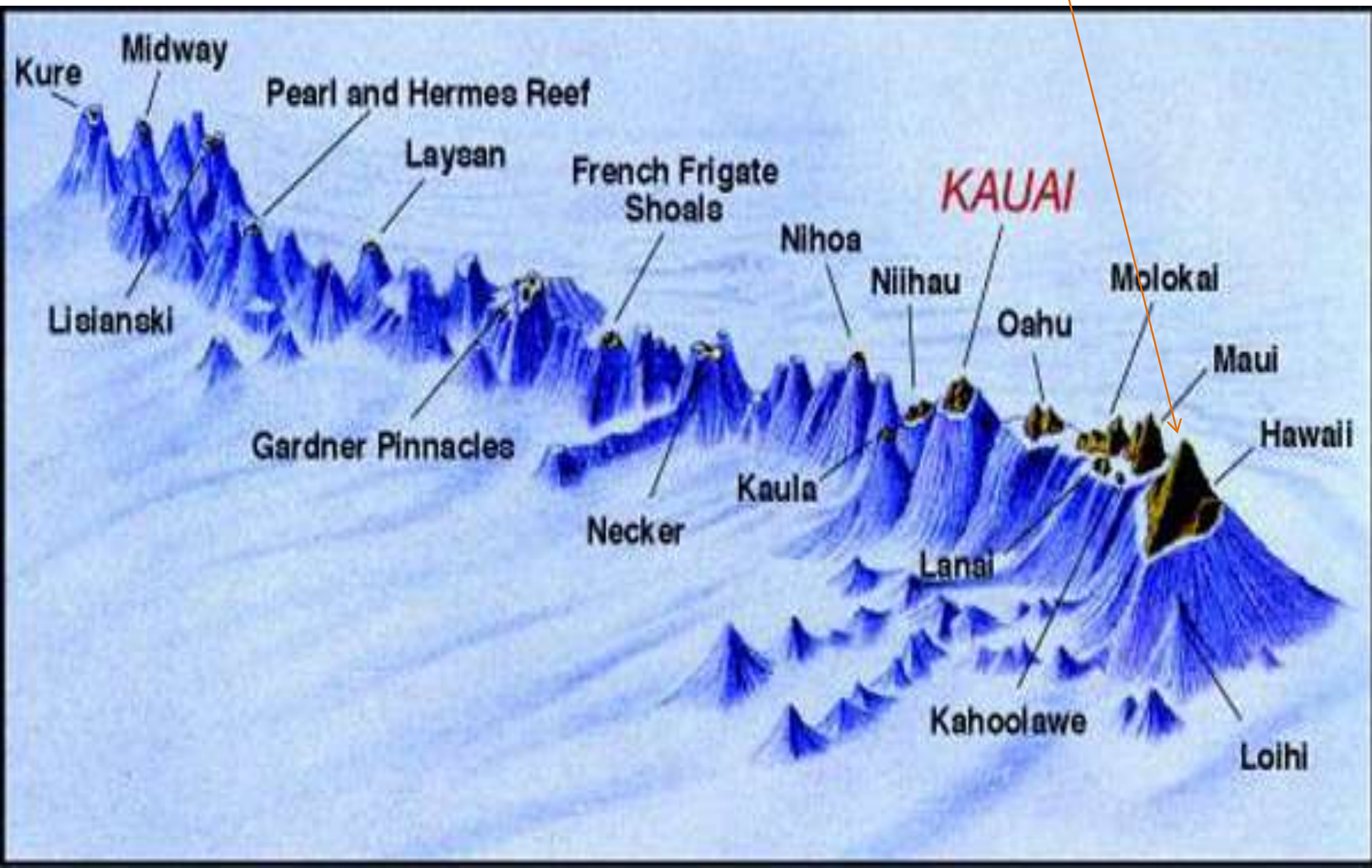
Who has looked DOWN INTO Diamond Head, the crater of an old shield volcano/mountain that helped form the island of Oahu?



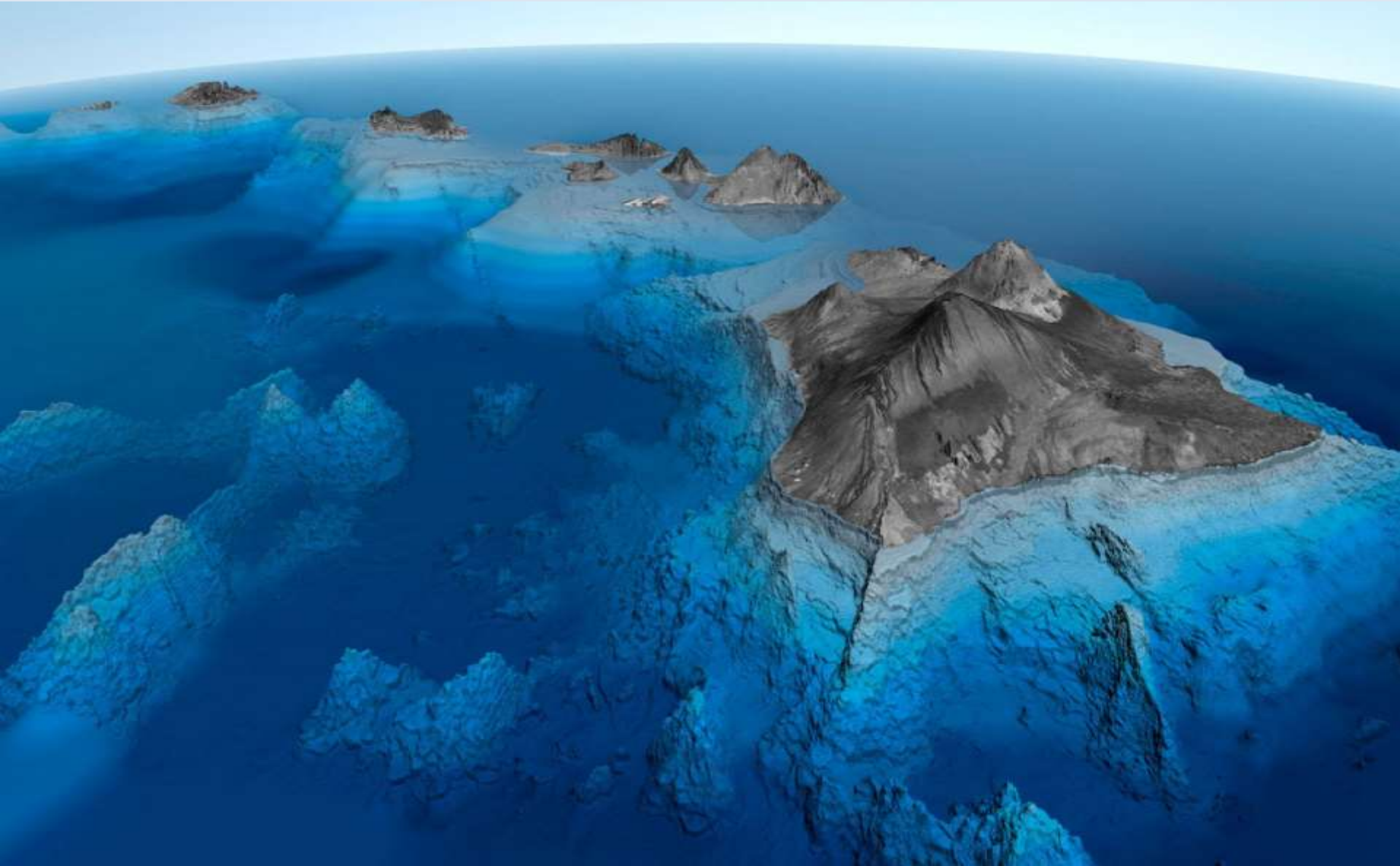
Hey! Let's talk some more about mountains/volcanoes formed "on" the ocean bottom!



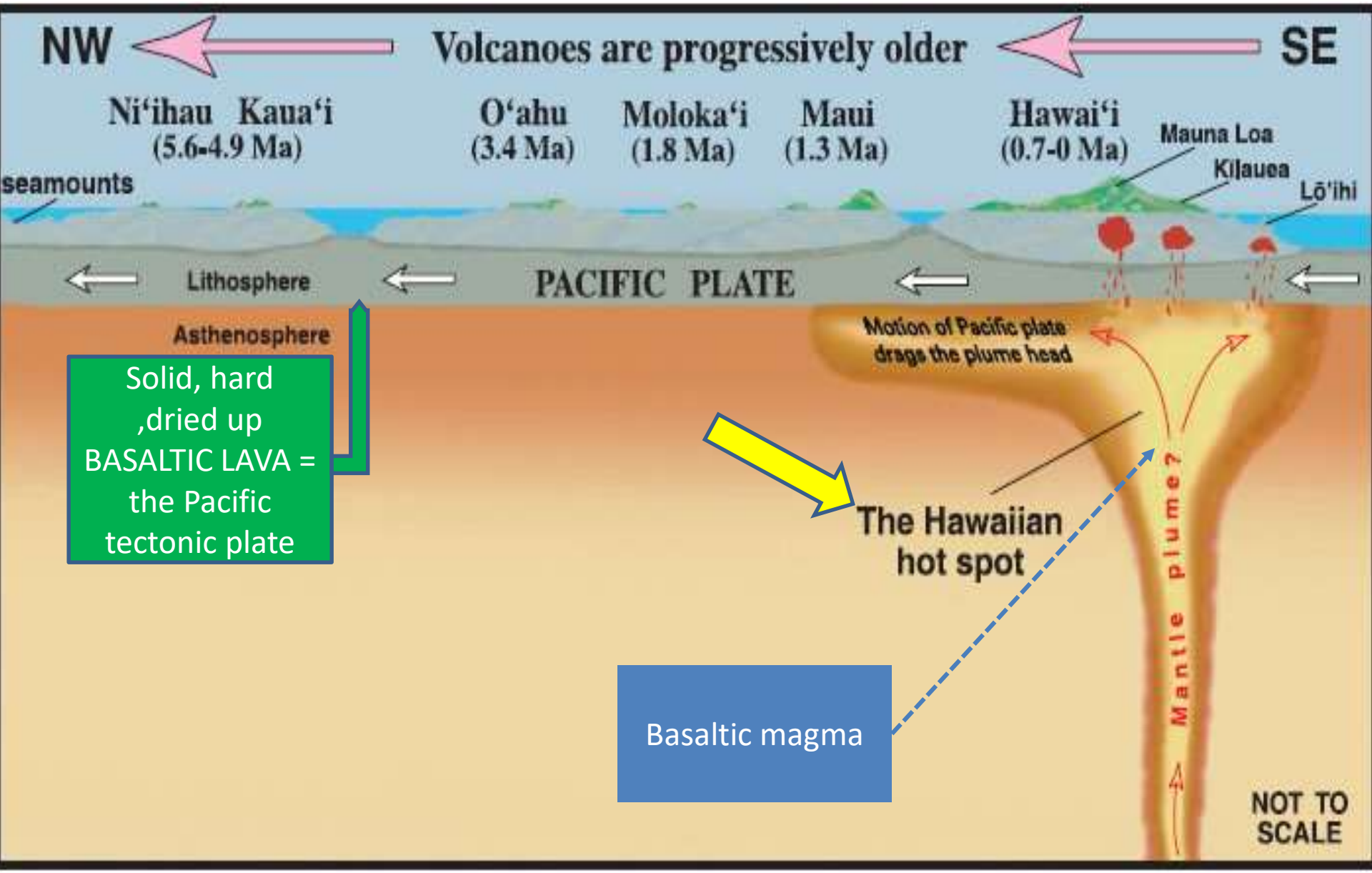
Mauna Loa, **a shield volcano/mountain** on the big Island of Hawaii, is 33,000 feet high (as measured from the floor of the ocean) This image also shows other shield volcanoes/mountains.



Underwater view of the 33,000 feet high (from the bottom of the ocean) Island of Hawaii.



This entire Hawaiian Mountain Range was/is formed as the result of a **HOT SPOT OF BASALTIC LAVA**. This is another way that mountains are made.

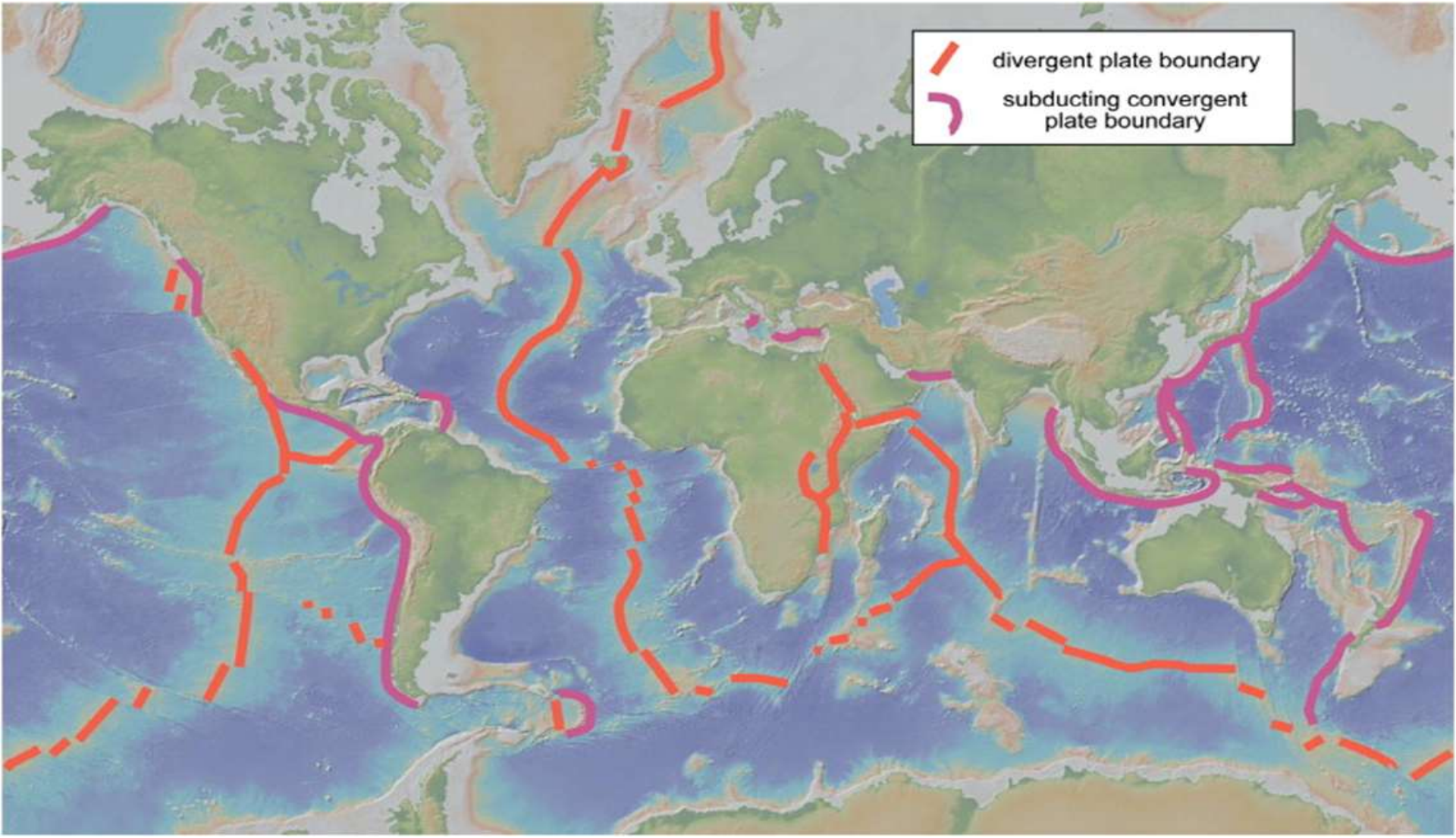


I had heard that **most volcanoes and mountains** are located on the bottoms of the oceans!

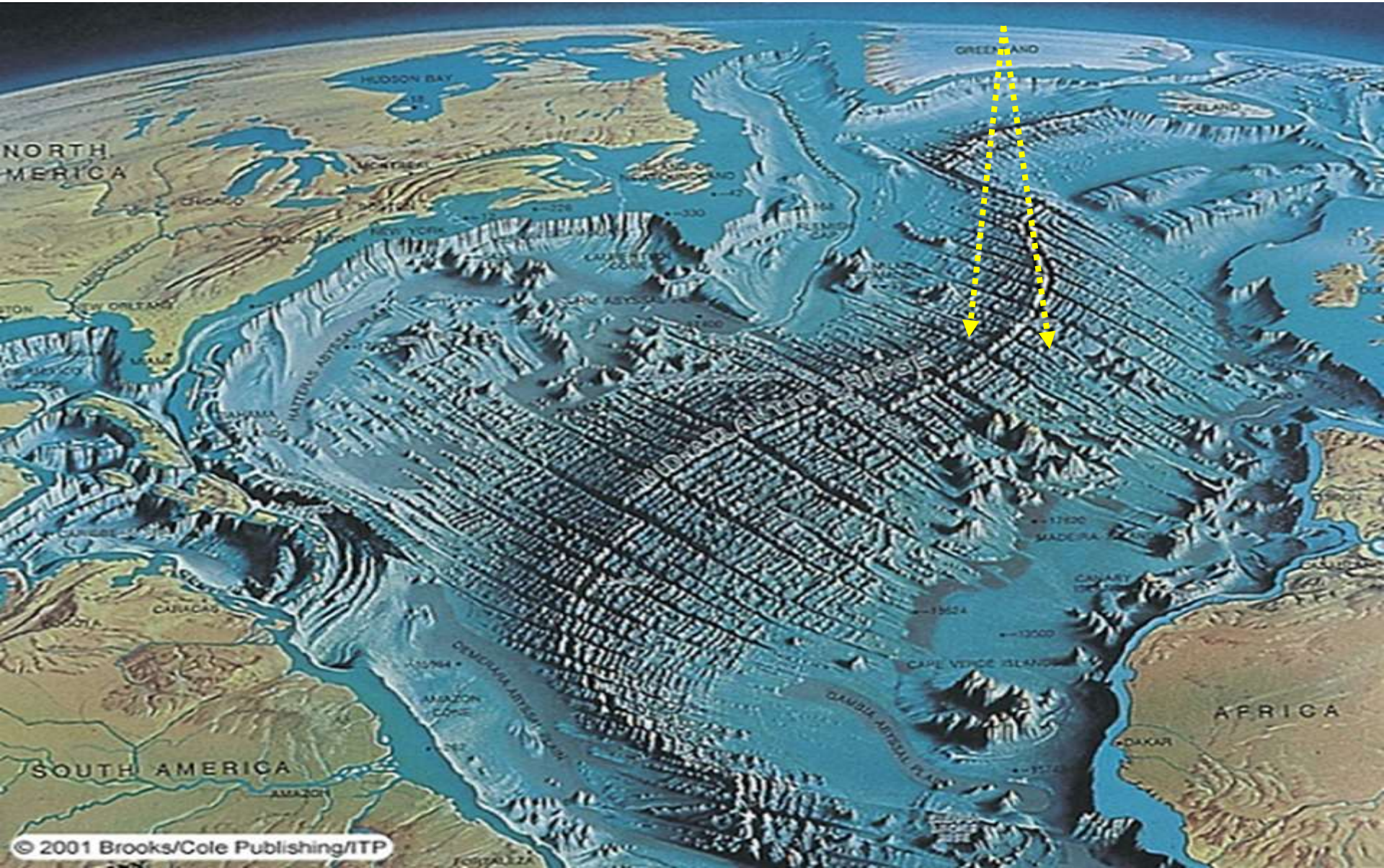
Is that true?



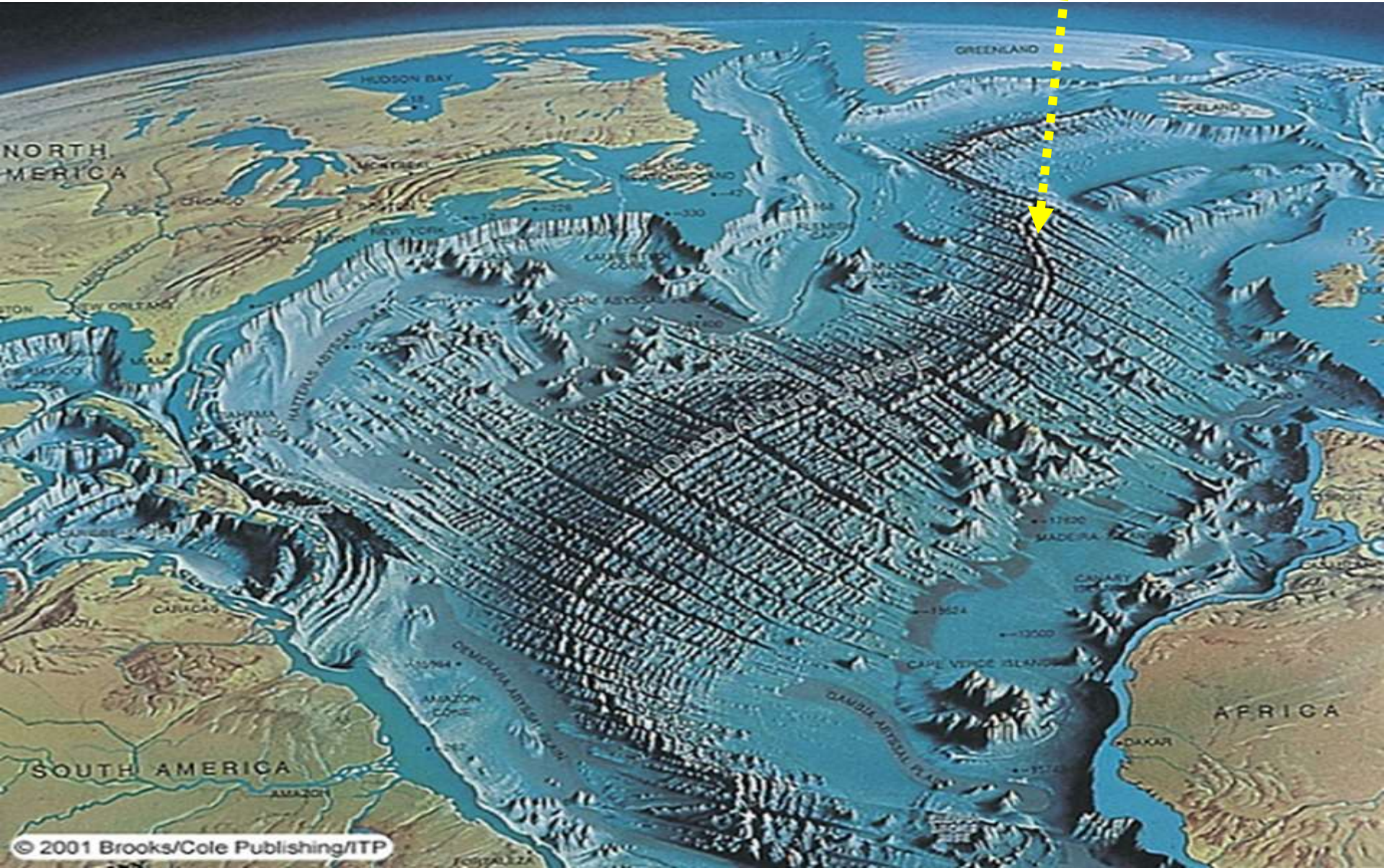
We saw a similar image above, but here again we see ***ORANGISH COLORED LINES*** indicate the location of the **oceanic ridges/DIVERGENT tectonic plate boundaries.** At these DIVERGENT TECTONIC PLATE BOUNDARIES the plates are MOVING AWAY from each other→ eruption of Basaltic lava→ Forming submarine volcanoes and ***MOUNTAIN RANGES*** in the process.



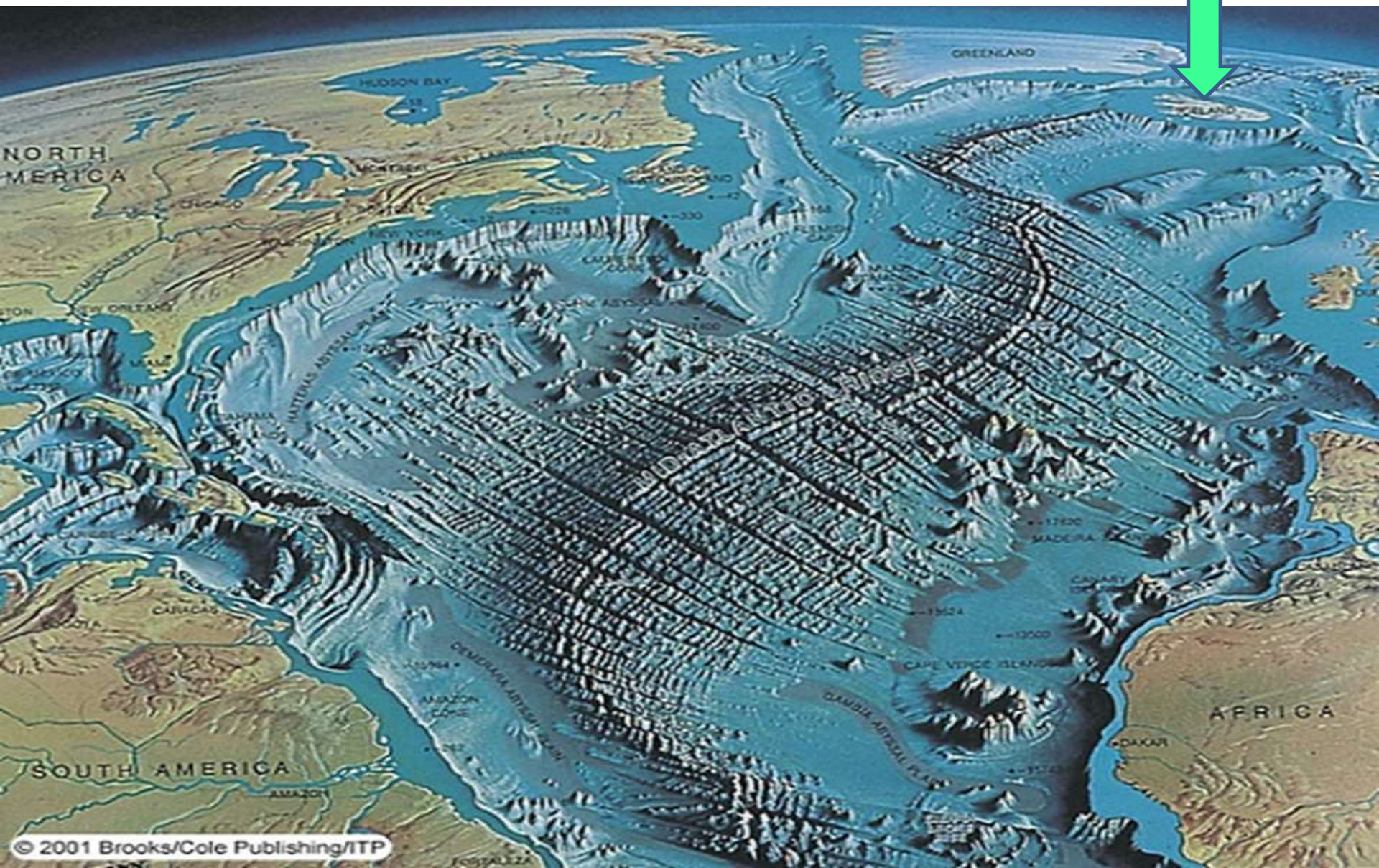
The basaltic lava produces (forms) a mountain range, called the MID ATLANTIC RANGE. The width of this range ranges from 1000 to 1,500 miles.



This makes these diverging-plate-areas the largest volcanoes in the world.



Here is ***the Island of Iceland***, formed by lava coming up through the opening between the diverging plates, (and from HOT SPOTS)



We know about SUBDUCTION, & DIVERGENCE of tectonic plates, and in each case mountains are made, but

what happens if

two continental plates

CRUNCH INTO EACH OTHER?

When two ***continental tectonic plates*** collide, they

shove/ squeeze/force upward

the:

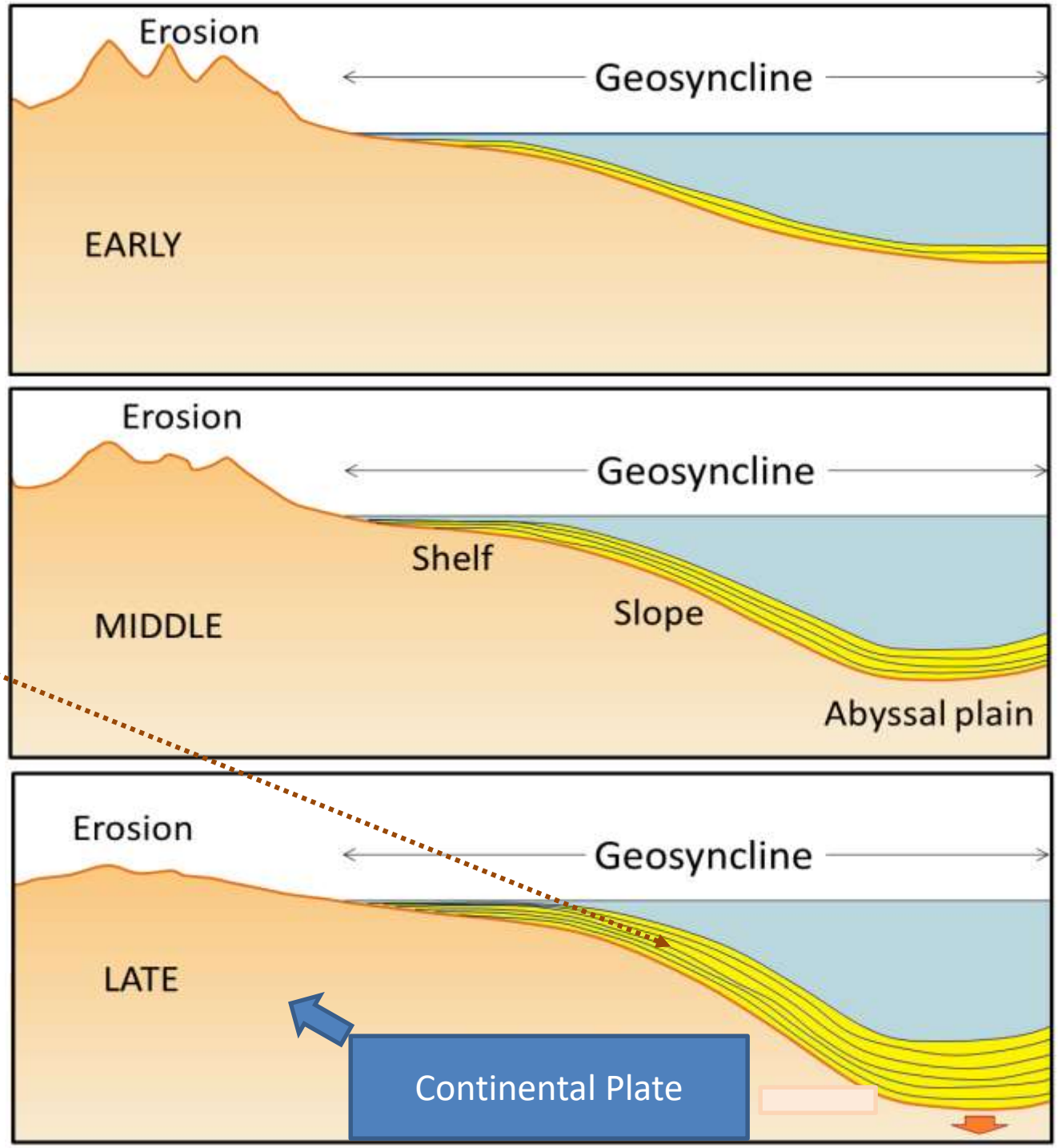
layers of the sedimentary rocks which existed between them,
as well as any other material, such as a mountain range,
and finally the fronts of the plates themselves.

These pushing actions form very high mountains,
which we call
FOLD BACK MOUNTAINS

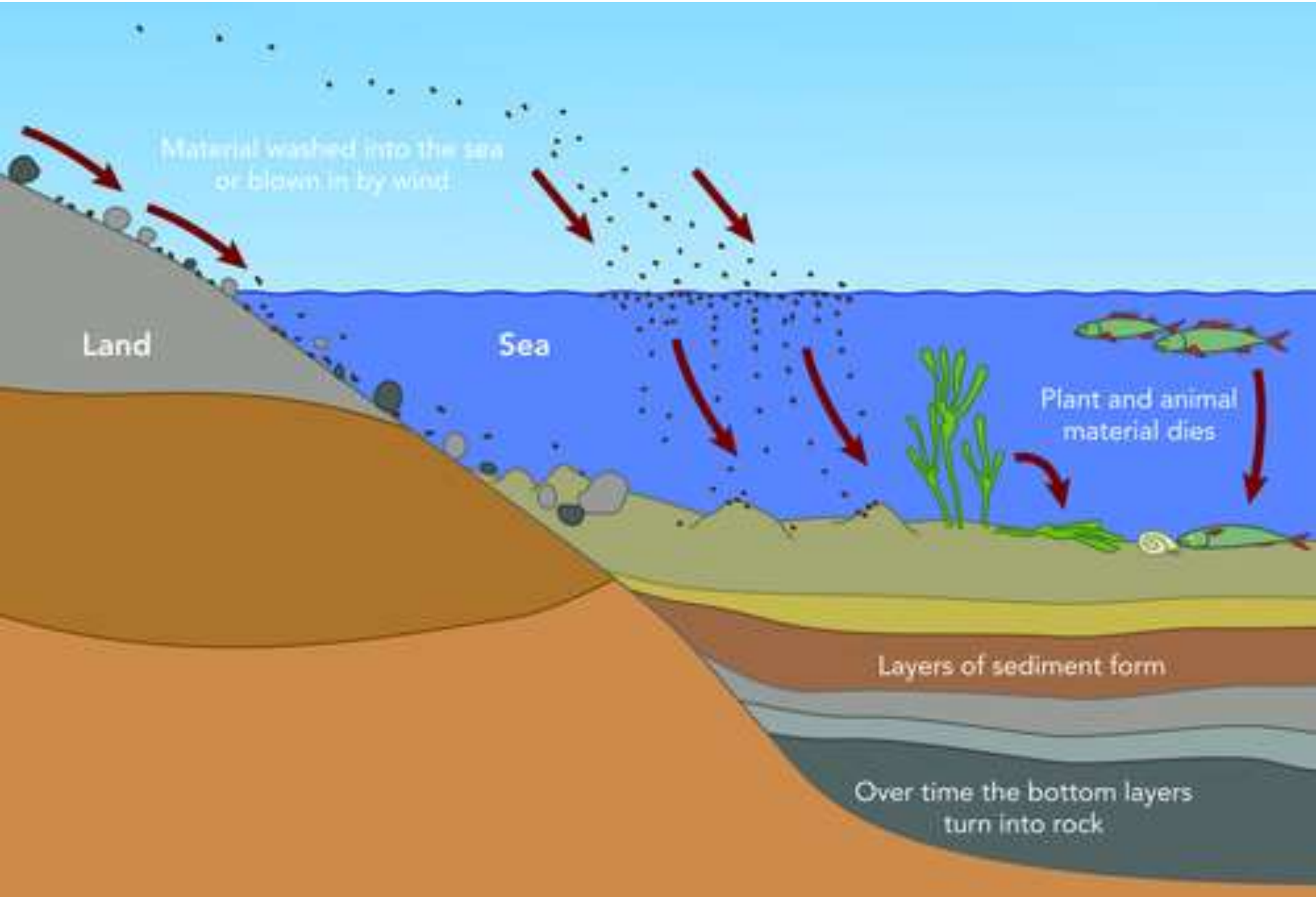
FOLD BACK MOUNTAINS! ?

Let's digress .

Here we see the location of those layers of sedimentary rocks in the geosyncline/ Geocline



Here is a simplified image of the process of forming layers on the bottom of our inland sea &/or the ocean.



Another image of the ocean bottom/bottom of our inland sea filled with layers of sedimentary rocks.



Let's look at what happened/is happening as the

Indian continental plate

and the

Eurasian continental plate

crunched/are crunching
into each other.

And what does any of this have to do with the layers of sedimentary rocks on the bottom of the ocean?

As the *Indian* tectonic plate and the *Eurasian* continental plate are shoved together, those layers of sedimentary rocks which lay between them would be squeezed like a throw rug..

If/When that happens, the sedimentary layers would be folded and faulted .

Concurrently, these layers,

ALONG WITH THE EDGES OF THE TECTONIC PLATES ,

would be shoved upward.

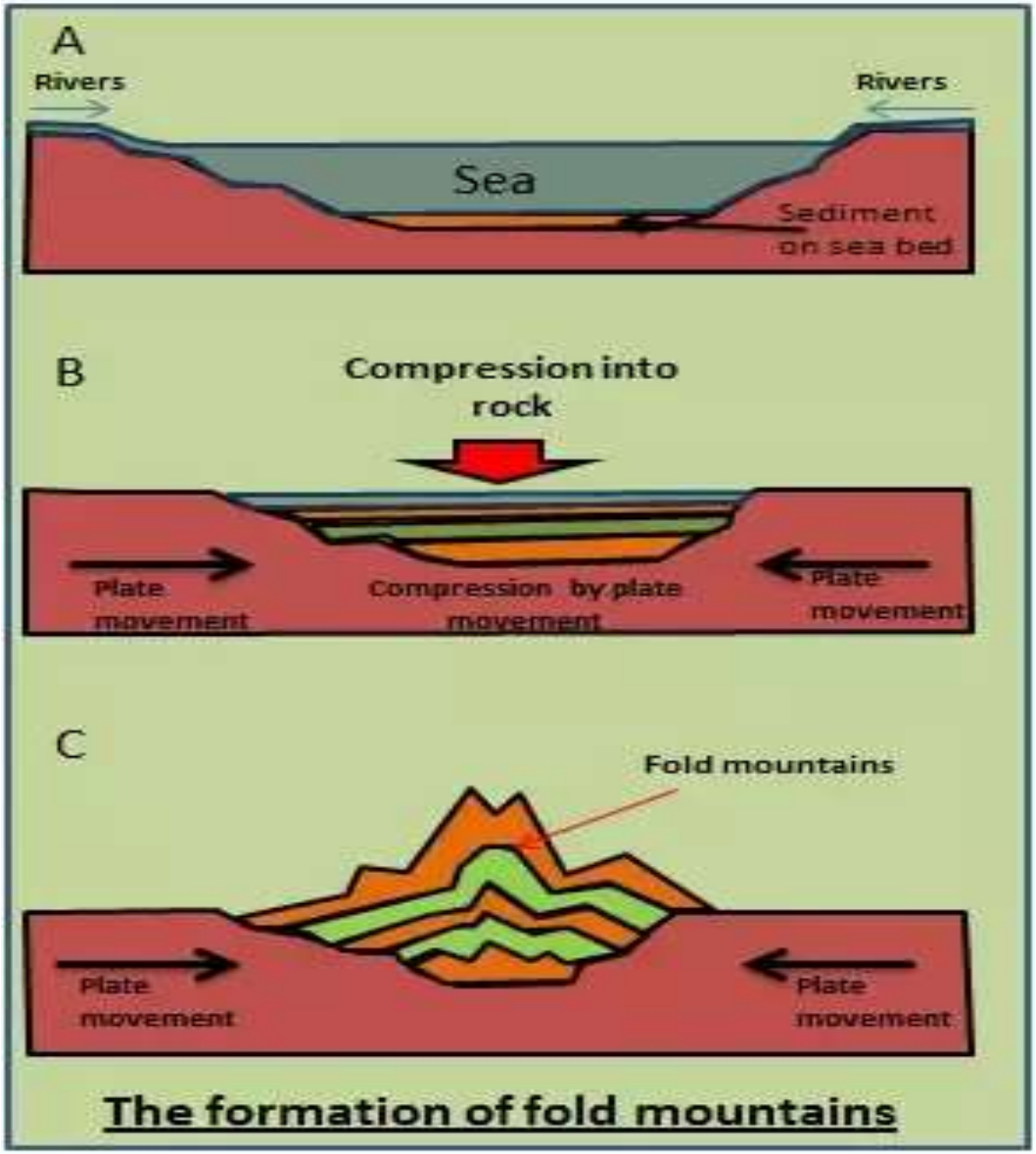
making the mountains.

These processes would eventually form an enormous mountain range, the Himalayas, with over 100 peaks exceeding 21,000 feet in elevation.

This same process would (is forming) the Alps.

(And in the past formed the Alleghenian mountains, the predecessors of the Appalachian mountains)

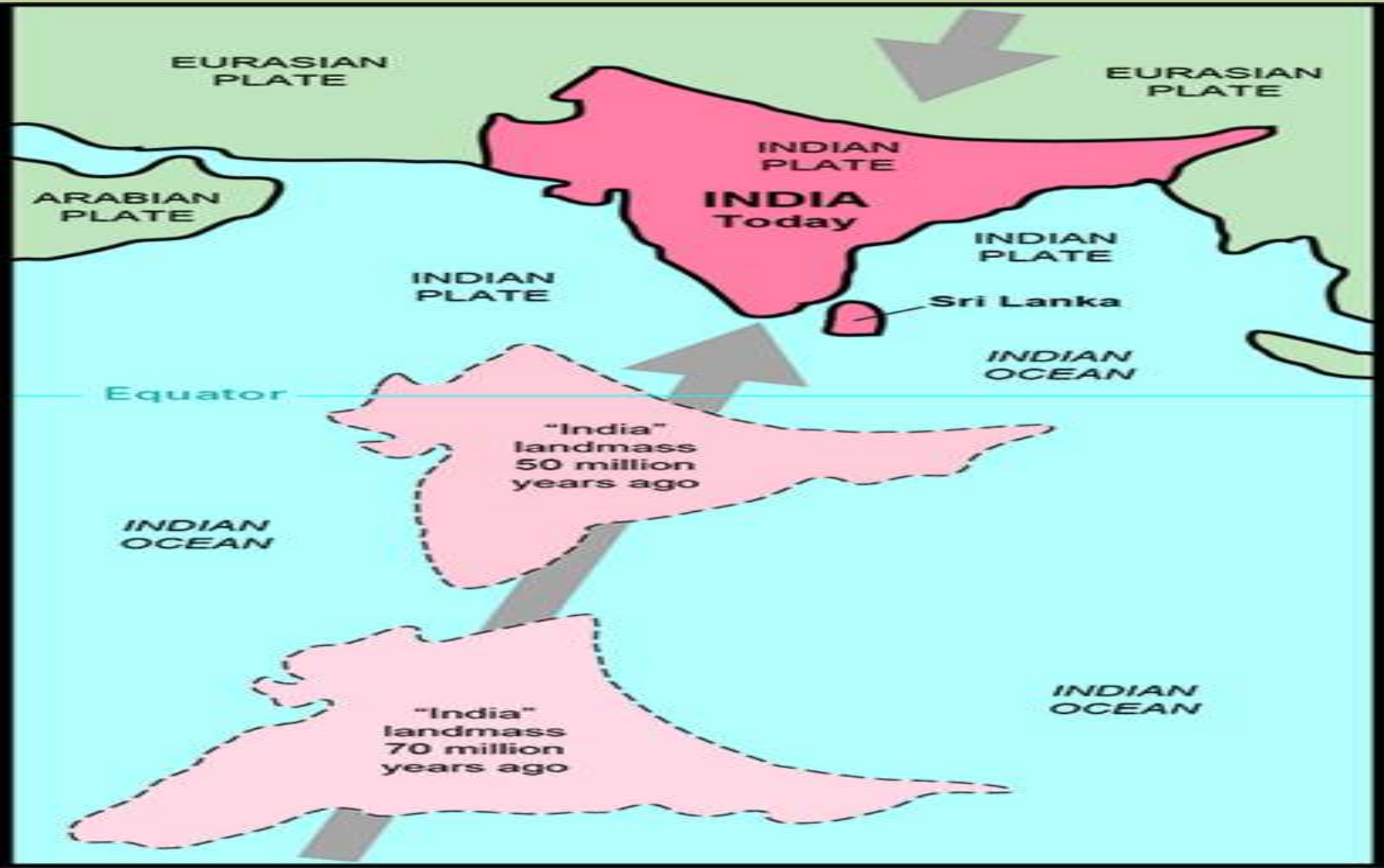
In this image we see the sedimentary rocks in the geocline/syncline between the **Indian** Continental Tectonic plate and the **Eurasian** Continental Tectonic plate being folded/faulted and shoved upward.



A side view, showing the FOLDS/FAULTS of the sedimentary layers of rocks which were squeezed, as well as the larger folds which resulted from the squeezing together and consequent elevation of the edges of the plates themselves..

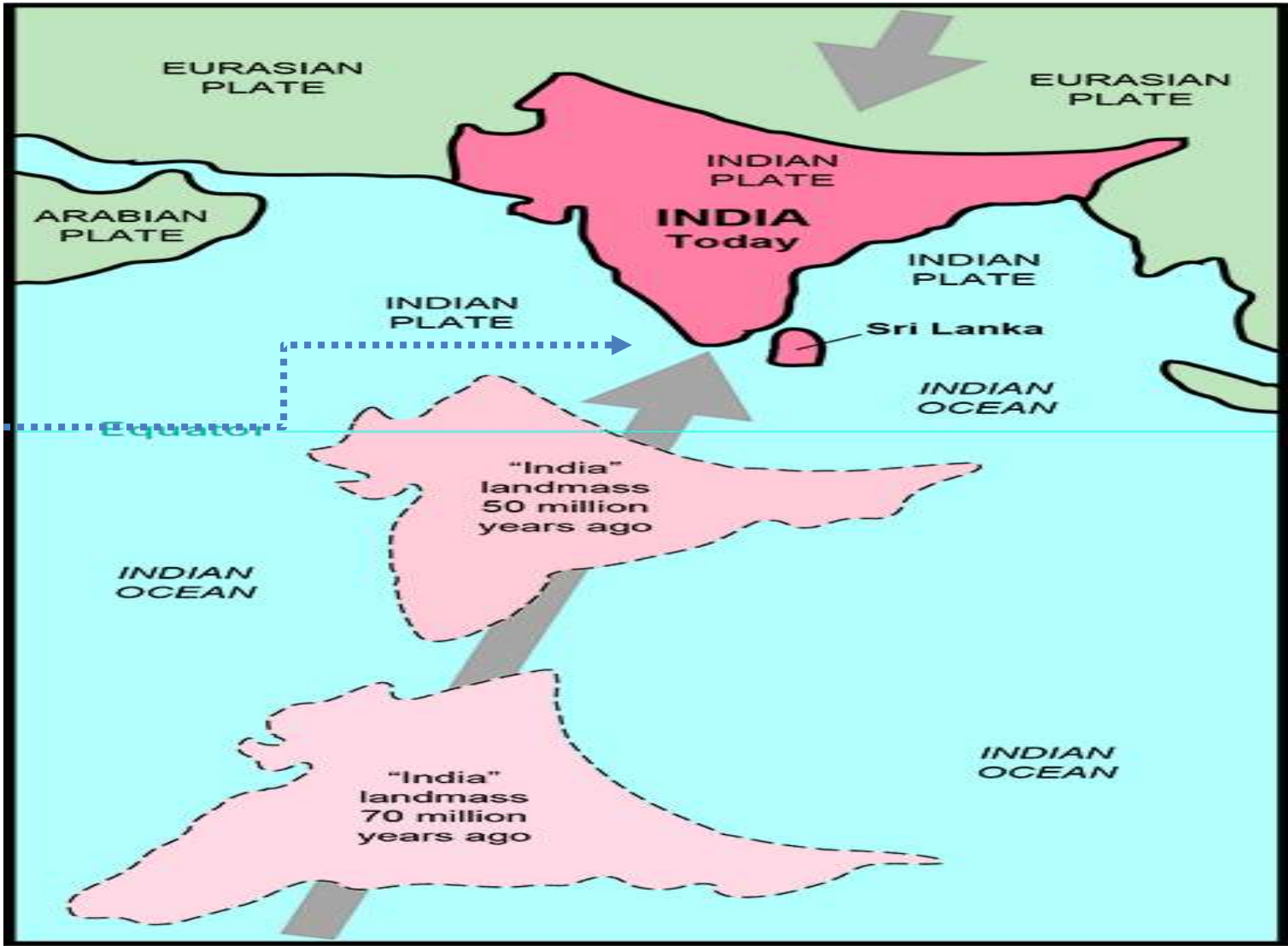


Let’s jam the Indian continental plate into the Eurasian continental tectonic plate and see what happened.

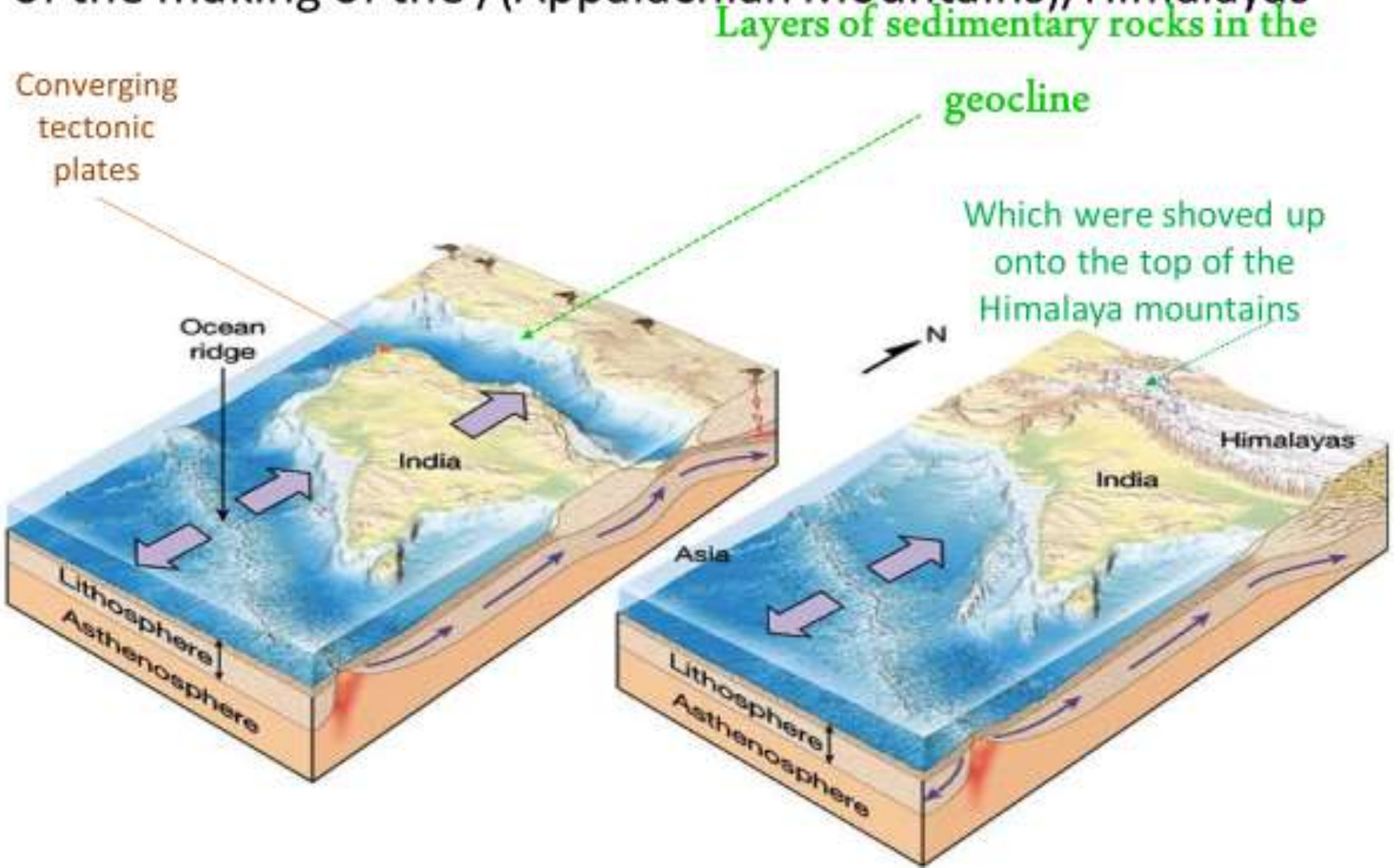


Layers of sedimentary rocks were in front of the Indian tectonic plate, in the GEOSYNCLINE/GEOCLINE. As it moved toward the Eurasian Plate it pushed these layers up and over onto the Eurasian plate.

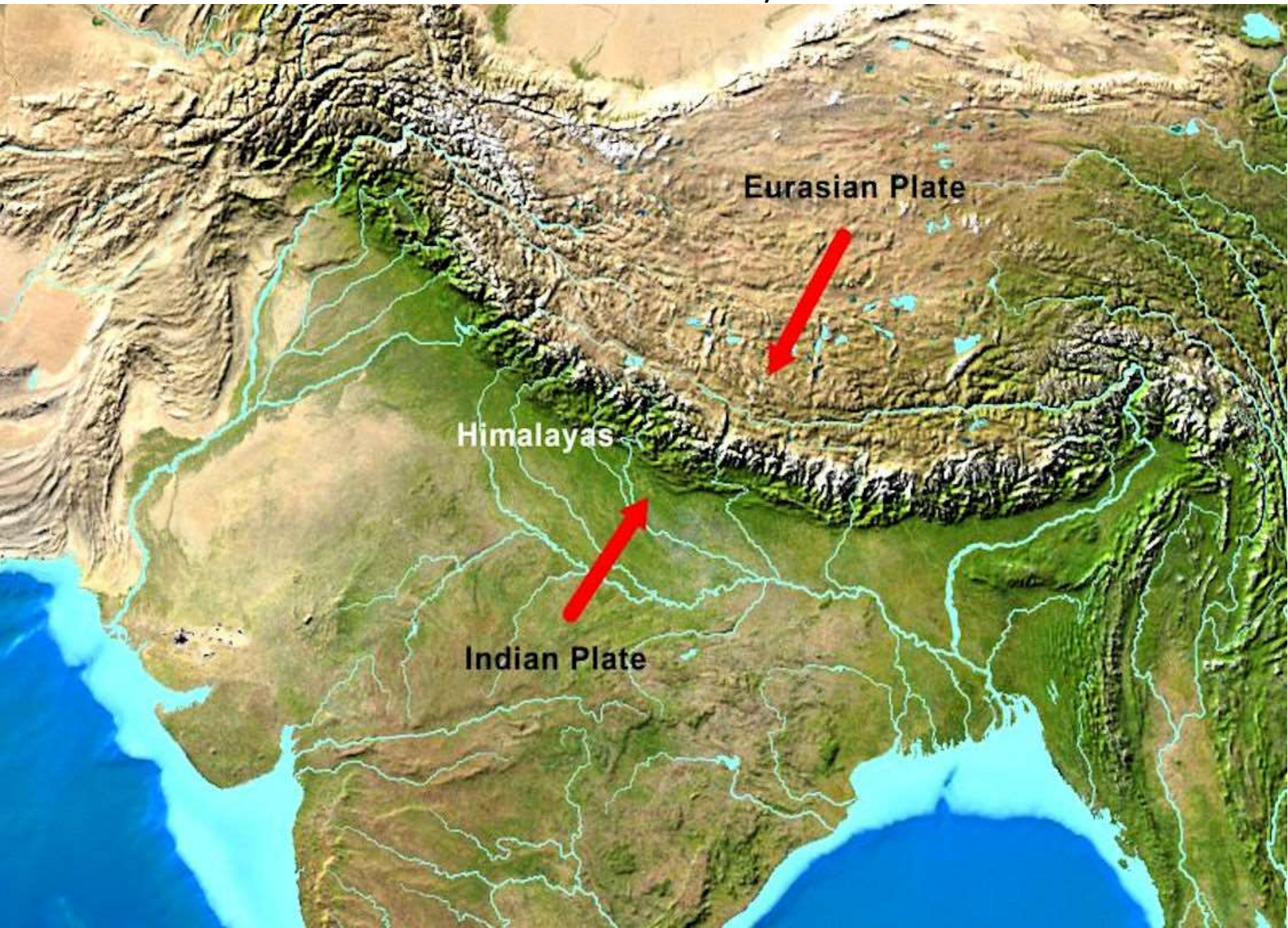
Location of the Geocline = layers of sedimentary rocks



Then these layers are squeezed together, as in this image of the making of the ~~/(Appalachian Mountains)/~~Himalayas



To form the Himalayas



sedimentary horizontal rock layers , originally formed in the geocline, now folded and forming a FOLD BACK MOUNTAIN



Mountains by Folding

- **Fold mountains are actually formed by crust which have been uplifted and folded (buckled or bent) by compressional forces.**



Rock that is put under extreme pressure for long periods of time (thousands or millions of years) will fold like clay.

Here again we see the folds of the previously layered sedimentary rock after it has been squeezed together and upward to form FOLD BACK MOUNTAINS.



Today, the **BIG** FOLD BACK MOUNTAINS in the world are:

the Himalayas, the Alps, and the Andes.

(We will look at the Alleganian/Appalachian mountains next week..)



A photo of **Mt. Everest**, one of the most widely known Fold back Mountains



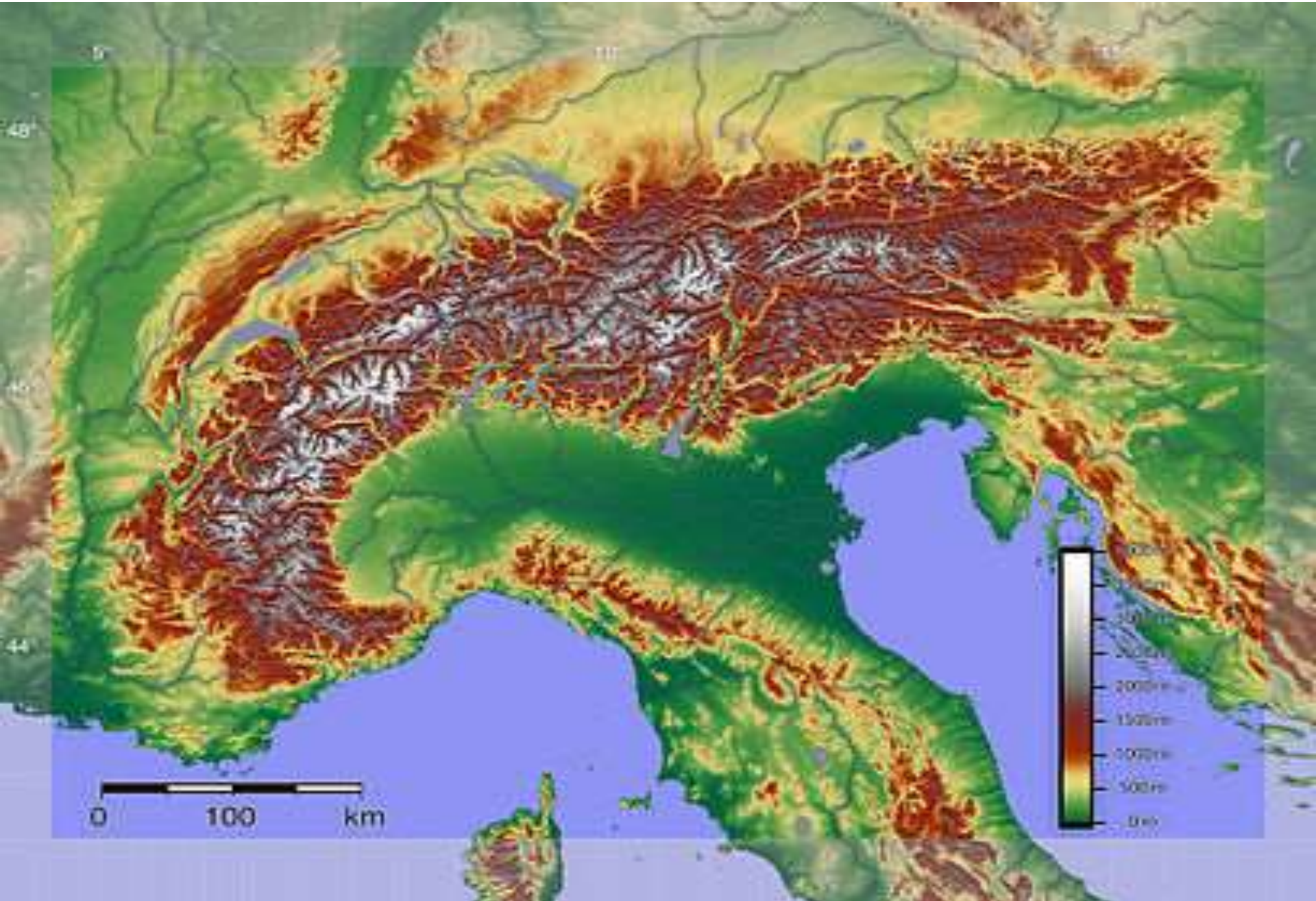
A closer look at Mt. Everest, with its sharp edges and its steepness, some of the characteristics of FOLD BACK MOUNTAINS.



Mount Dom, one of the Fold Back Mountains in the Swiss Alps



Location of the FOLD BACK MOUNTAINS called: **The Alps**.



THE FORMATION OF THE FOLD BACK MOUNTAIN RANGE WE CALL **THE Alps** BEGAN ABOUT 300 MILLION YEARS AGO

The Tethys sea (now called the Mediterranean) had developed between the Eurasian Plate and the African Plate/ Gondwana, at that time.

The layers of sedimentary rock which had been on the bottom of the Tethys (Mediterranean)Sea, were/are being squeezed between the colliding plates.

These layers,

along with the edges of both the continental African Plate and the Continental Eurasian Plate,

were/are being pushed upward,

causing the formation of the mountain range we call the Alps.

The rock structures of the Alps have been folded and fractured in such a manner that the

steep vertical peaks, characteristic of

Fold Back Mountains,

are easily seen.

These steep peaks seem to rise seemingly straight out of the rolling terrain near the base of these mountains.

These peaks include Mont Blanc, the Matterhorn, Mt. Rosa, Mt.Dom, Mt. Lyskamm, Mt. Weisshorn ,

all ~ 15,000 feet high Alpine mountains.

Of course we are all familiar with the steep sided FOLD BACK MOUNTAIN we call: The Matterhorn in the Swiss Alps.



The sun is setting!

The “Formation of Mountains” class is ***almost*** over!



Let's look at a 13 minute video that will tell us how the Alps, an example of FOLD BACK MOUNTAINS, were formed.
(Show this at the end of lecture 33 if time.)

https://www.youtube.com/watch?v=UITGt14KIlI

This is a 47 minute video of the formation of the Alps.

Begin at: 4:13

END at: 16: 39.

With this brief background, let’s look at: The Formation of the Alps , a fold back/fold belt mountain range.



The sun is setting!

The “Formation of Mountains” class **is** over!



See You Next Tuesday !

