The background of the slide consists of three sequential, slightly faded images of a thick, translucent, yellowish substance (silly putty) being poured from a glass. In the first image on the left, the substance is just starting to pour. In the middle image, it has formed a thick, elongated strand. In the third image on the right, the strand has become even thicker and more rounded at the bottom, demonstrating its unique material properties.

Have a play with the silly putty and then talk in groups about its material properties. How does it behave on different timescales? Is it a solid, a fluid, both, or something else?



WHAT IS THE INSIDE OF THE EARTH LIKE?

Deep Earth Explorers

Before We start...

- When we're sharing ideas as a group only one person should be talking at a time.
- If I ask you to discuss something in small groups, make sure that everyone gets a chance to share their ideas in the group.
- I'll warn you when you only have 30 seconds left to finish your discussions.
- When I ask you to stop talking, I need you to stop quickly.
- If at any point you have a question, just raise your hand.
- Also if at any point you can't see or hear something, raise your hand.

WHAT IS A
GEOSCIENTIST
LIKE?

WHAT DOES A
GEOSCIENTIST
DO?



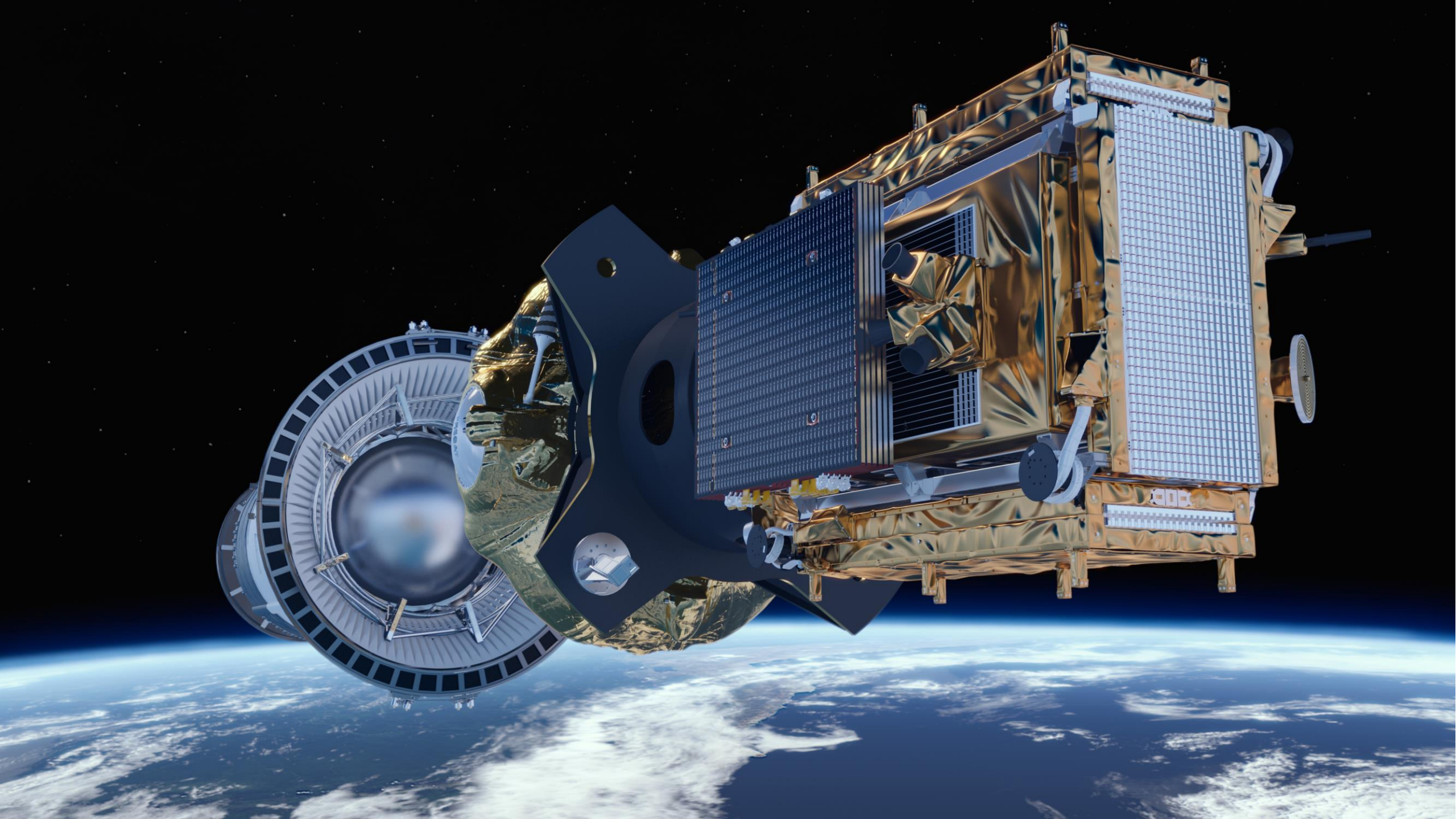




















Geosciences

A subject concerned with the workings of the Earth and other planets. It includes study of the climate, oceans, atmosphere, life and evolution, volcanoes, rocks, earthquakes, the deep interior of the Earth, and these same phenomena on other planets.



THE DEEP EARTH IN
THE MEDIA

JOURNEY TO THE CENTER OF THE EARTH



THE CORE



A large, irregular red ink splatter or blotch serves as the background for the text. The splatter is centered and has a textured, painterly appearance with various shades of red and some darker, almost black, areas. It is surrounded by smaller, lighter red droplets and splatters on a white background.

EXPERIMENT 2

Convection

The transfer of heat by the movement of hot material upwards and cold material downwards.

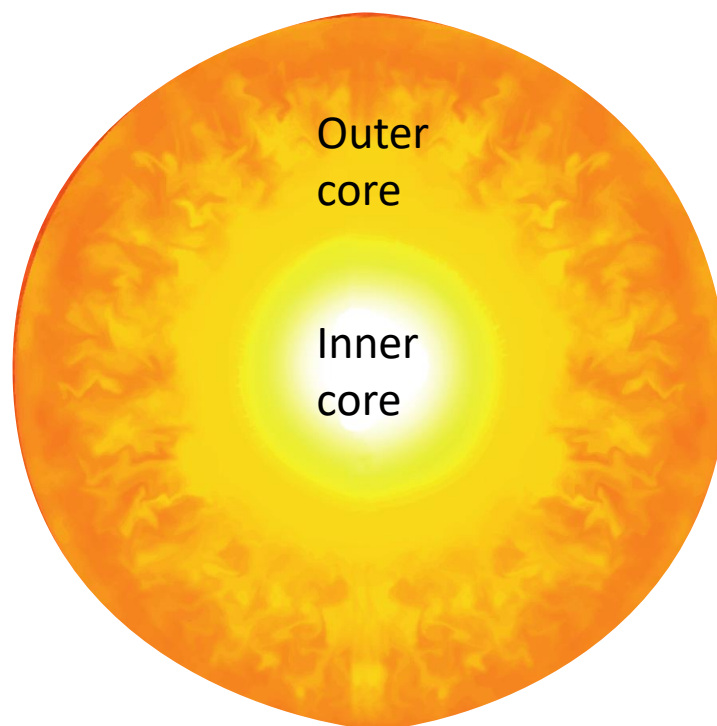




A large, irregular red ink splatter or blotch serves as the background for the text. The splatter has a textured, watercolor-like appearance with various shades of red and some darker, almost black, areas. It is centered on a plain white background.

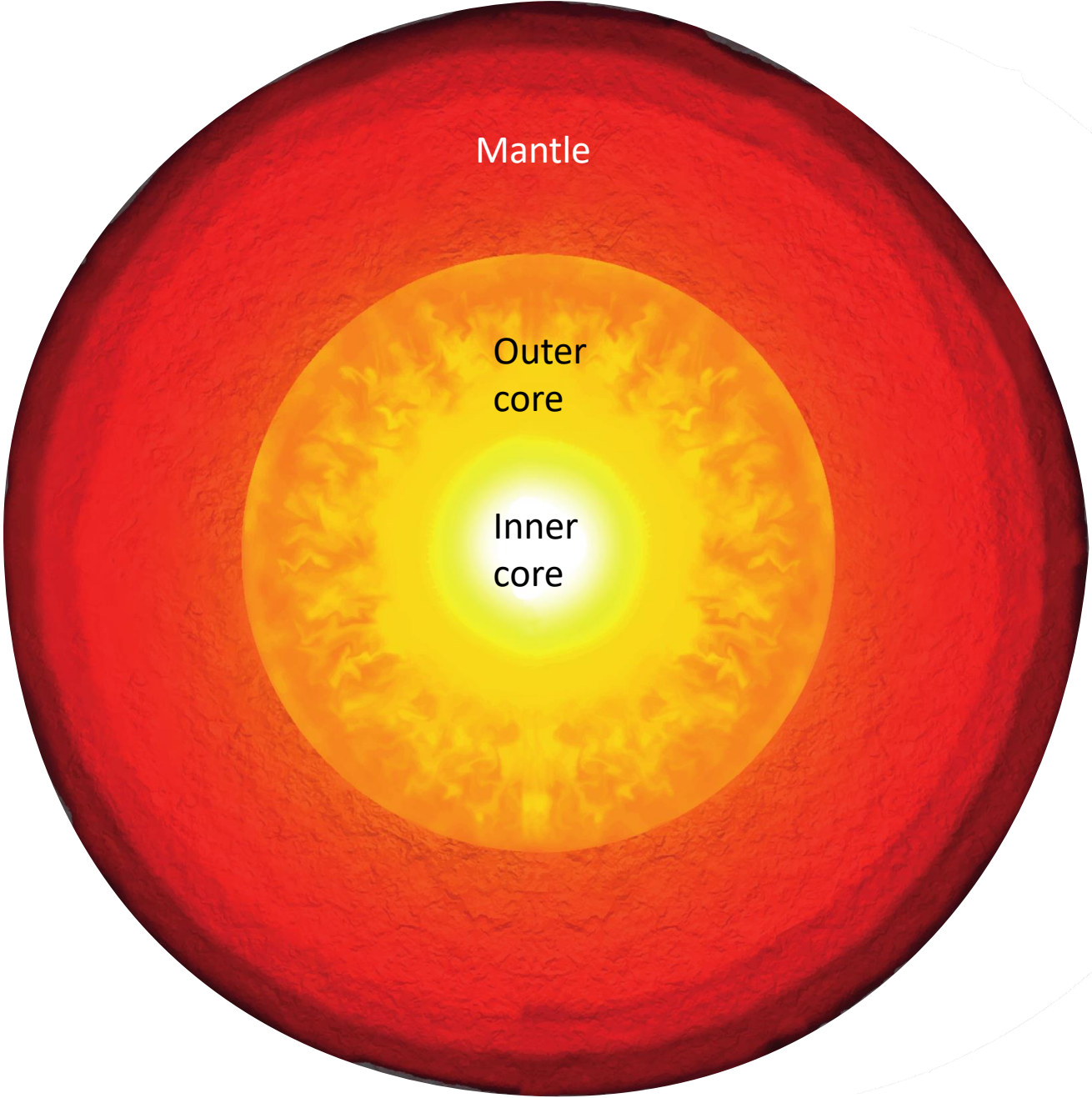
INSIDE THE EARTH





Outer
core

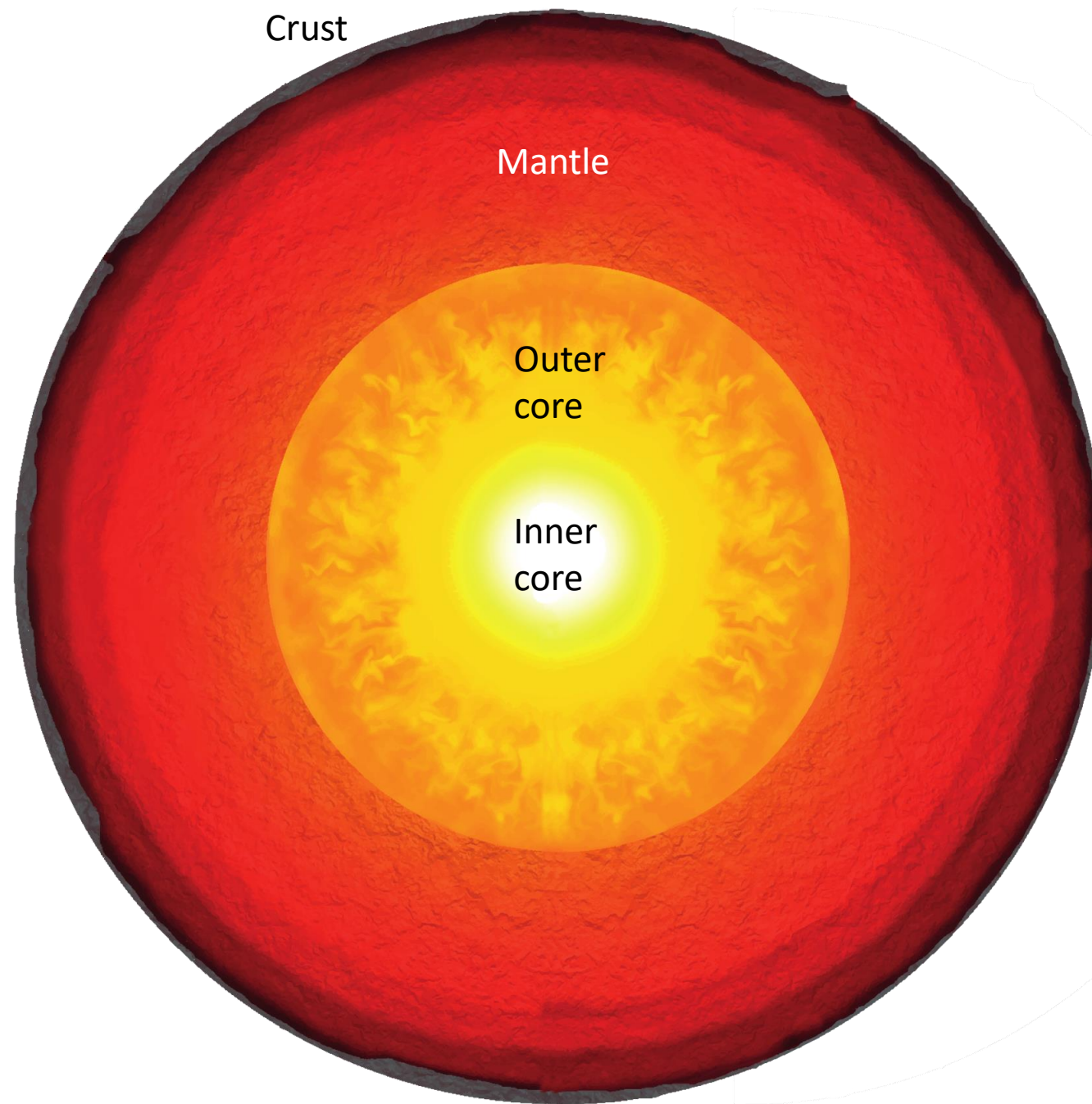
Inner
core



Mantle

Outer
core

Inner
core



Crust

Mantle

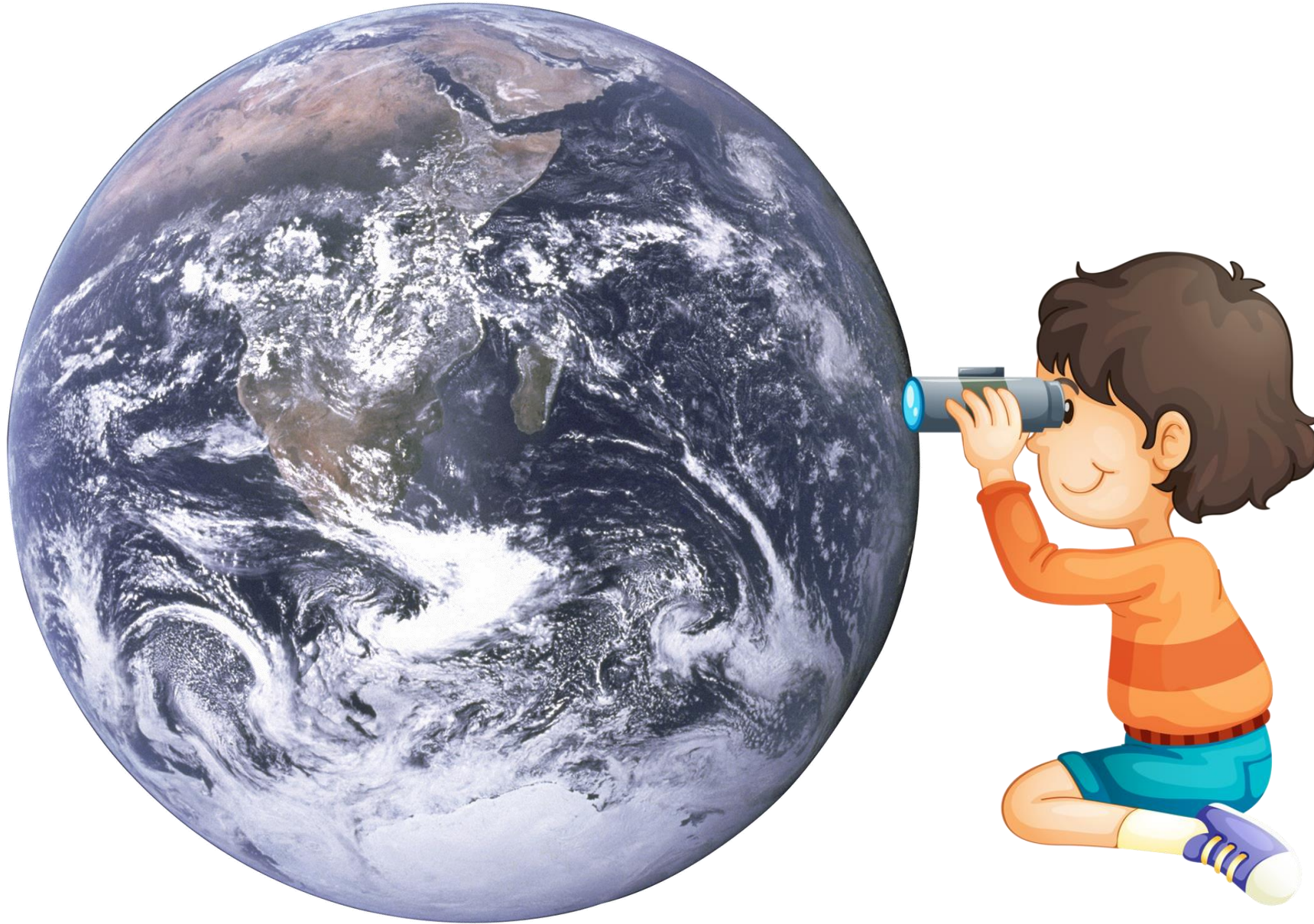
Outer
core

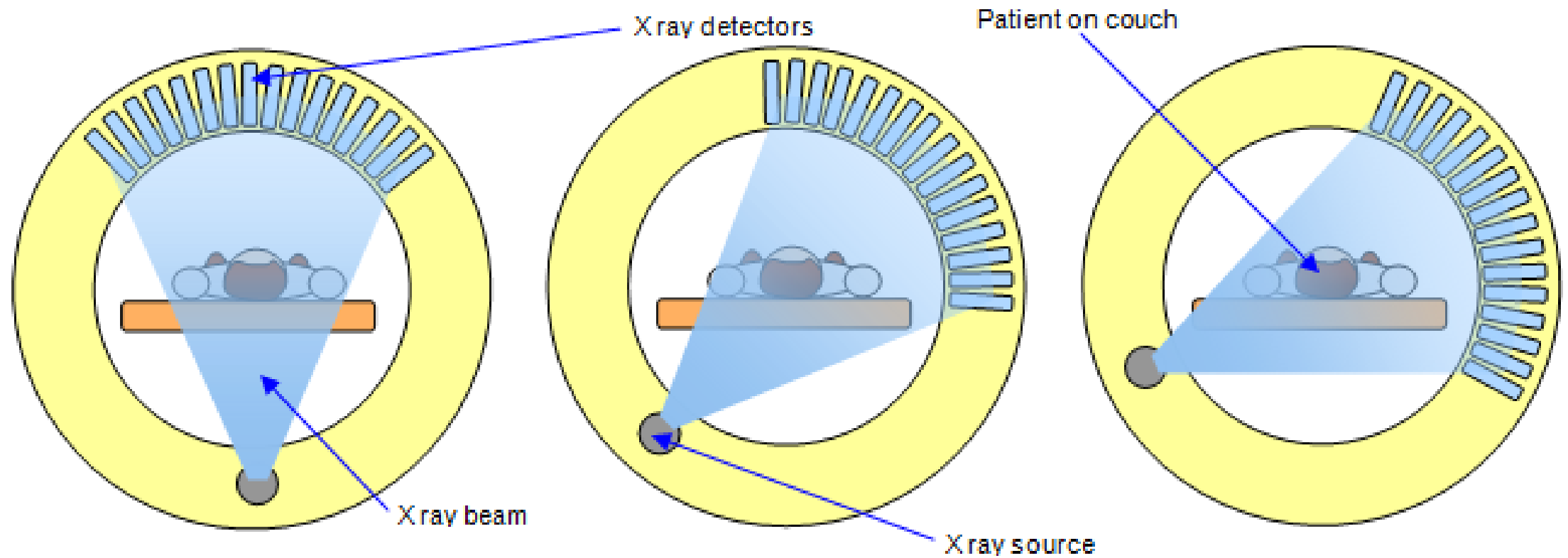
Inner
core

Mantle

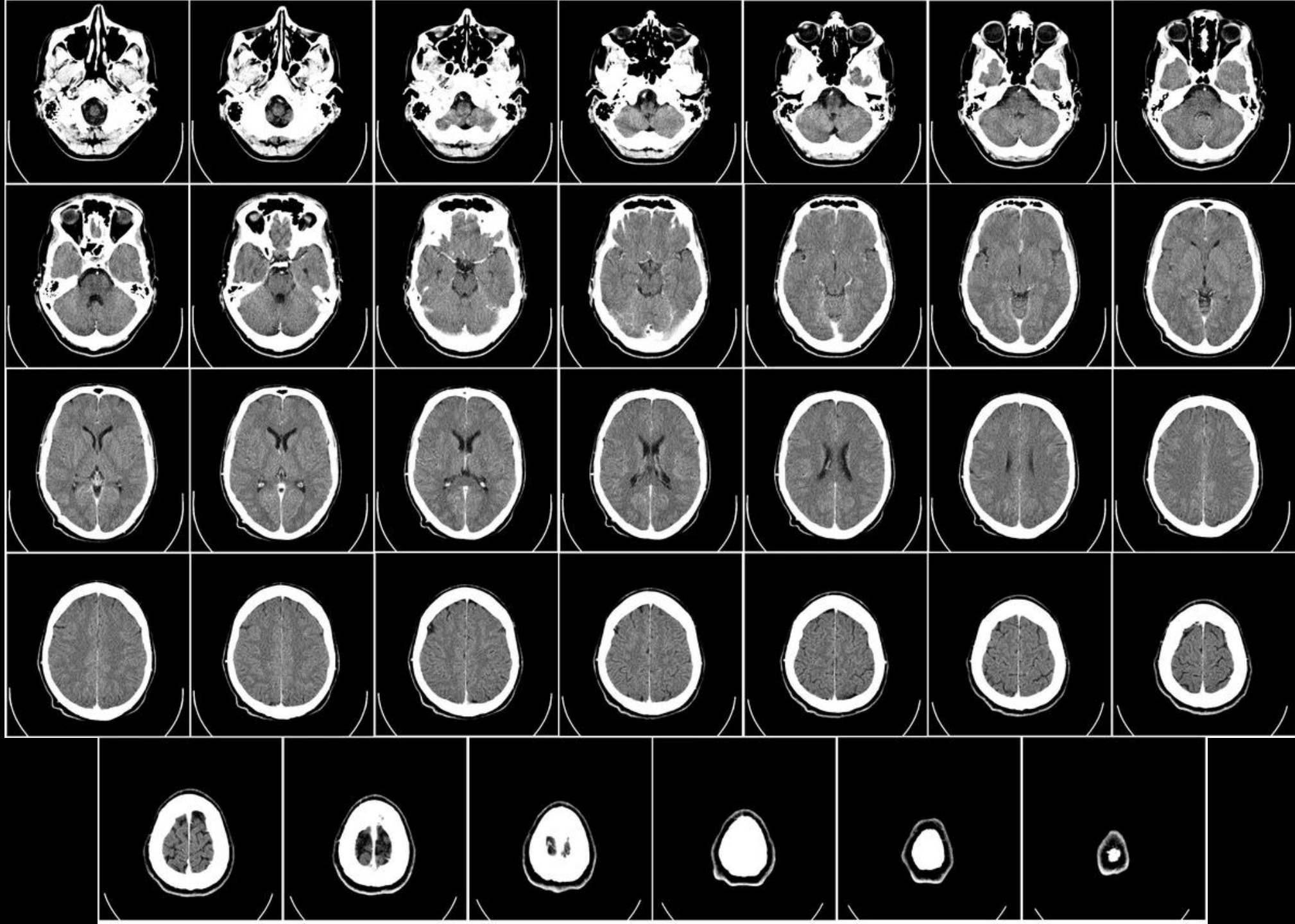
The second layer of the Earth, below the crust and above the outer core, which makes up 84% of the Earth's volume .

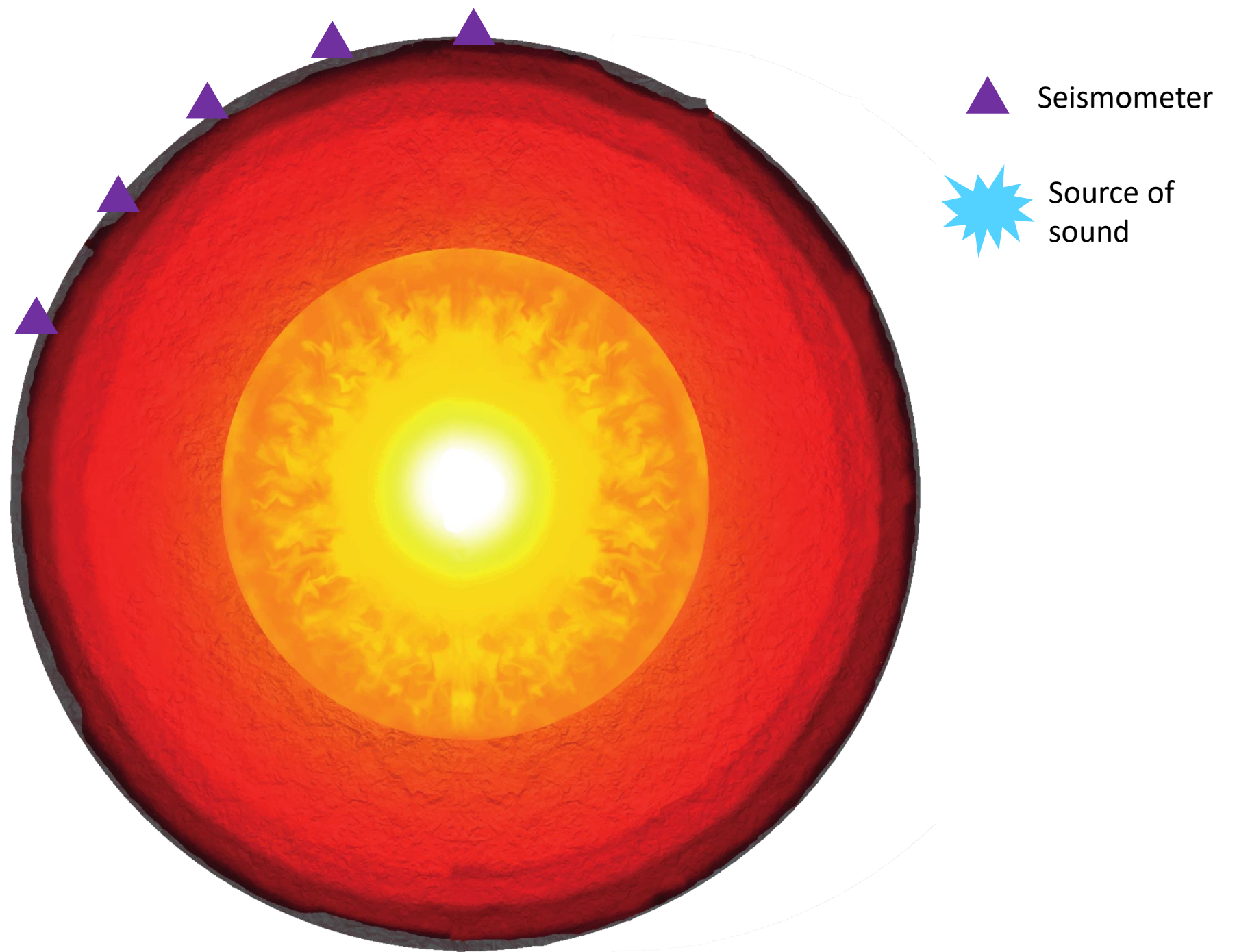
HOW DO WE
LOOK INSIDE
THE EARTH?

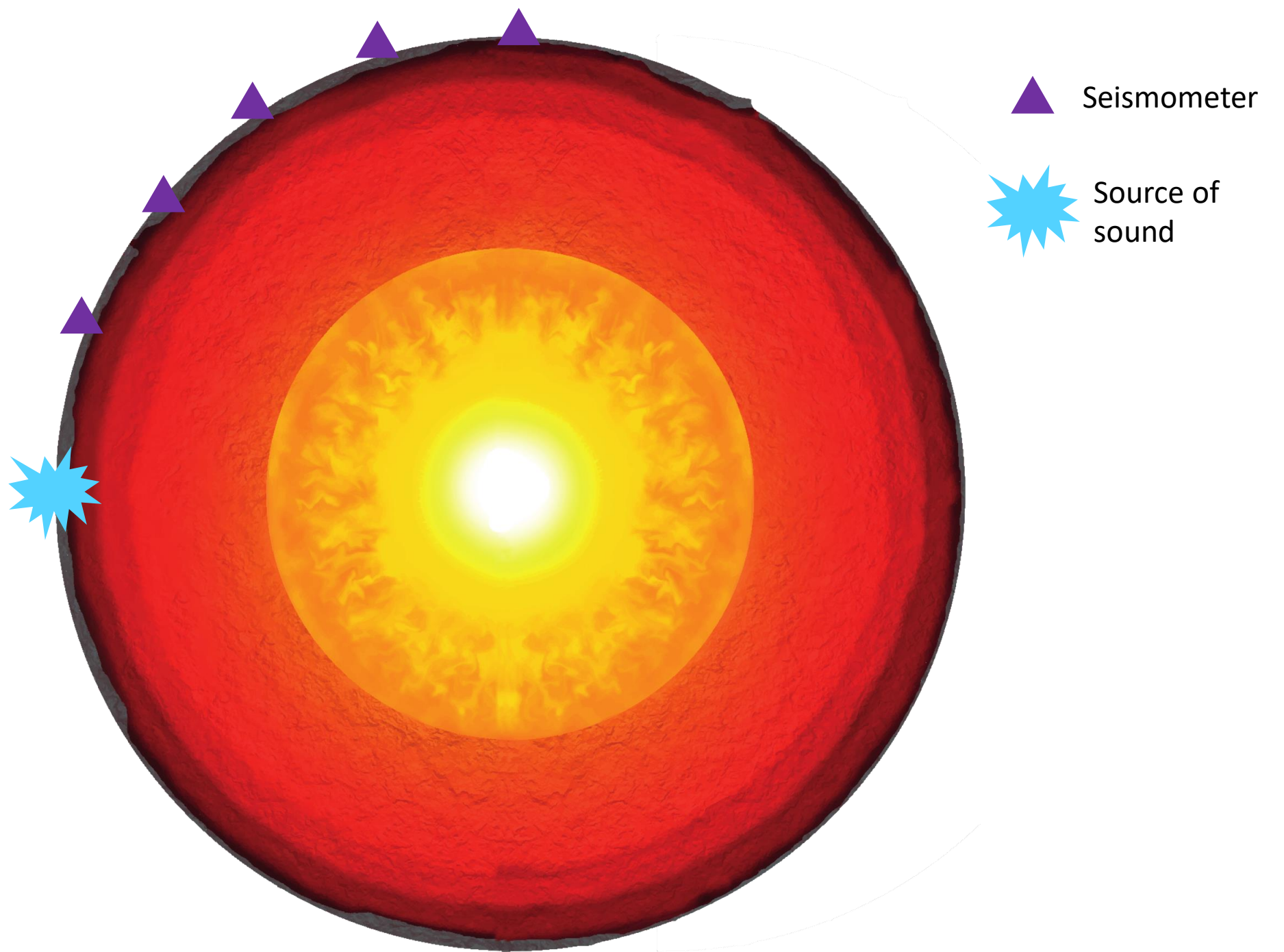


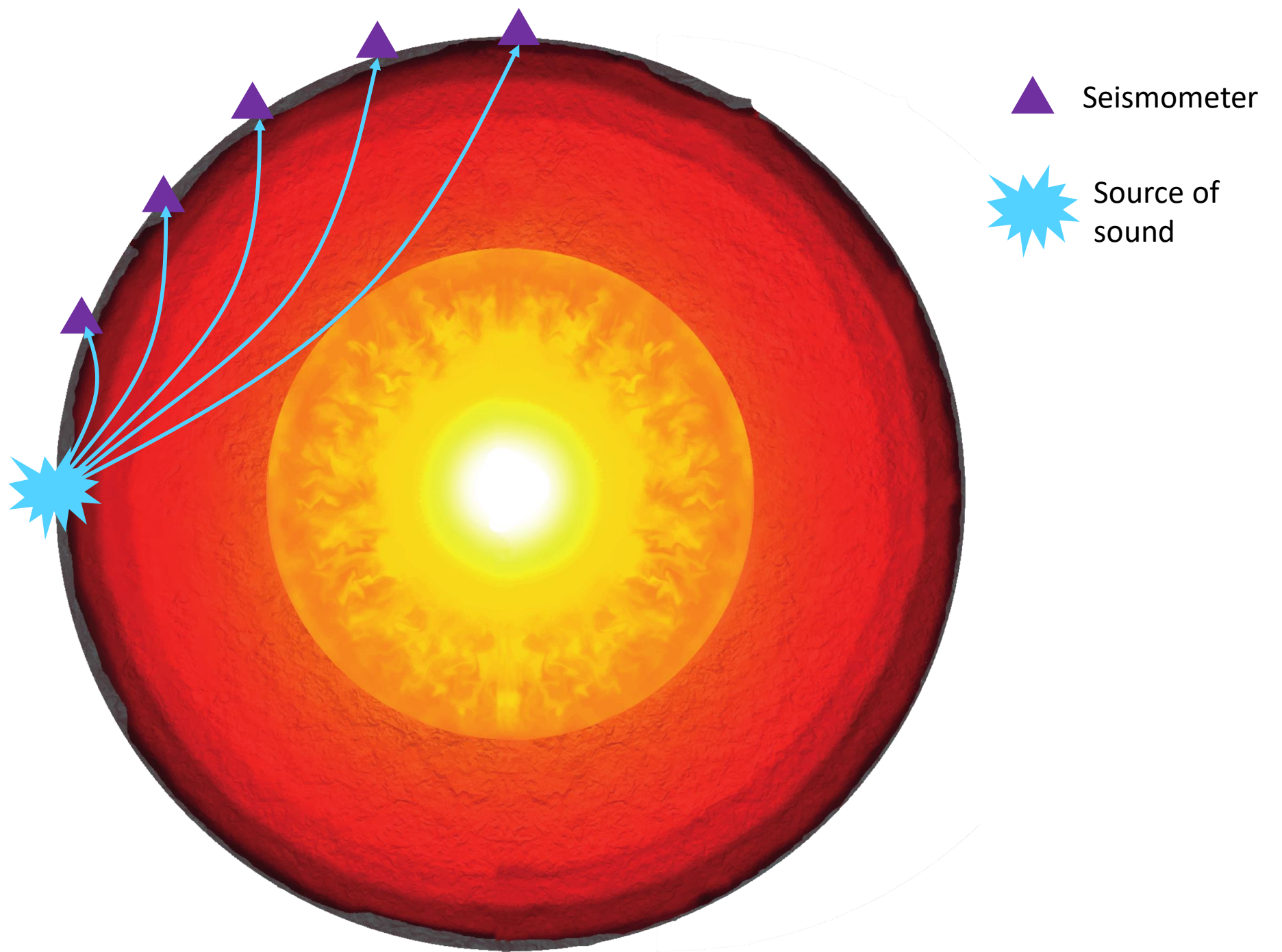


CT scanner with the X ray source and detectors shown in three positions



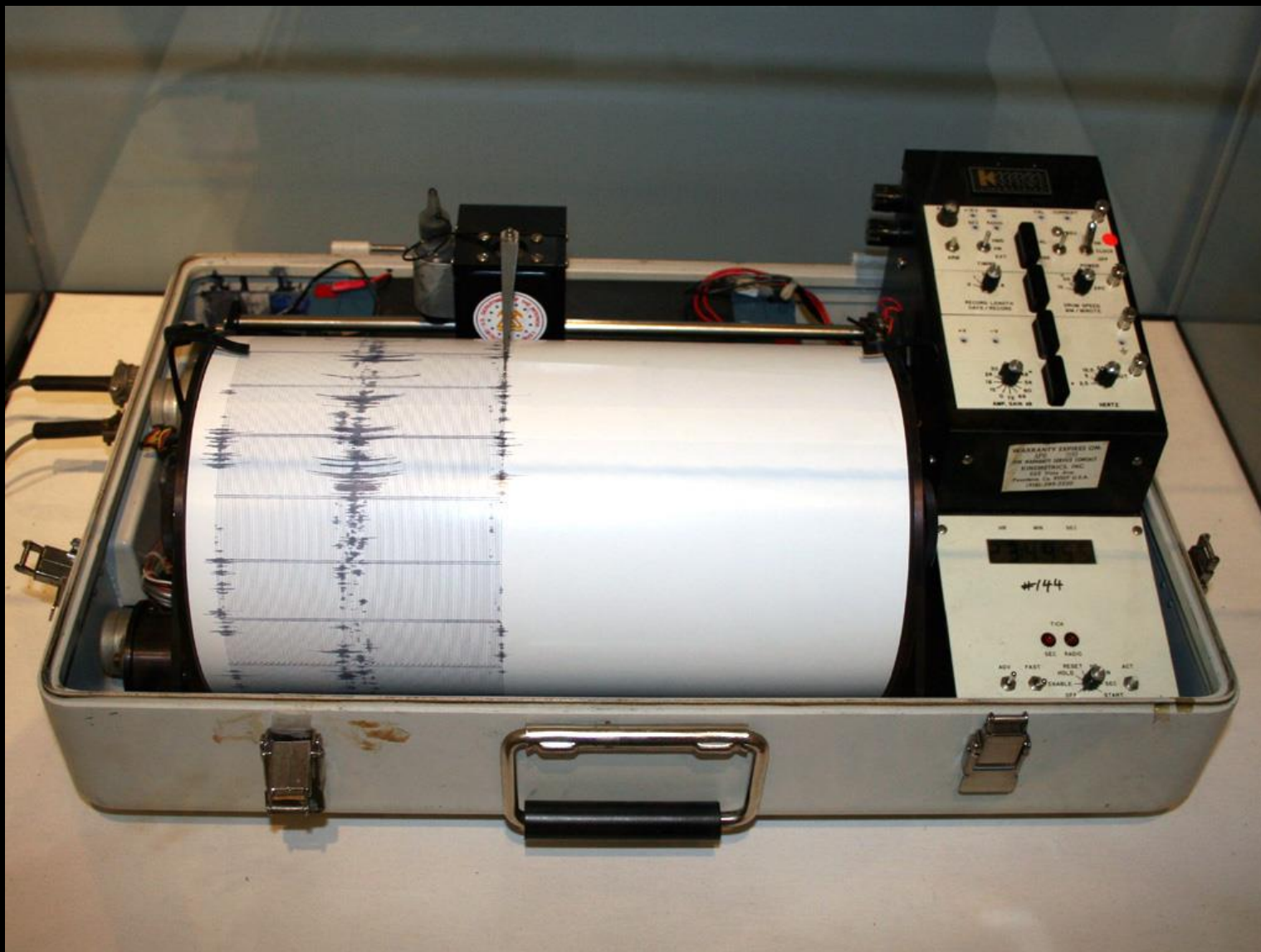






Seismic Waves

Vibrations (sound) which pass through the solid Earth.



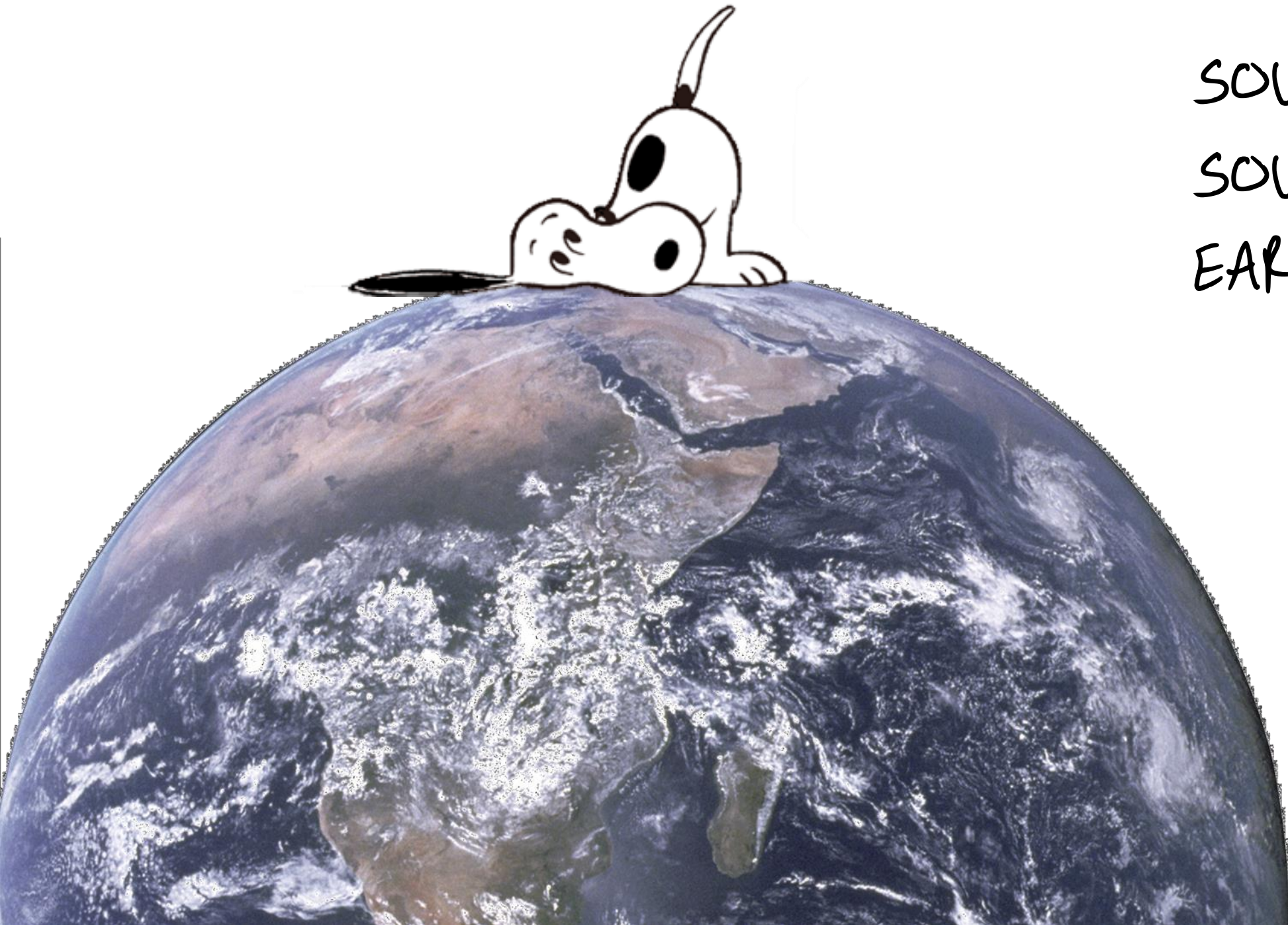
Video:

https://www.youtube.com/watch?v=o_ala-N-7KU



Seismometer

A sensitive instrument which measures the vibrations of the Earth's surface caused by seismic waves.



SOURCES OF
SOUND IN THE
EARTH?



[Visit this page to see a live earthquake map:

https://earthquake.usgs.gov/earthquakes/map/#%7B%22autoUpdate%22%3A%5B%22autoUpdate%22%5D%2C%22basemap%22%3A%22terrain%22%2C%22feed%22%3A%2230day_m25%22%2C%22listFormat%22%3A%22default%22%2C%22mapposition%22%3A%5B%5B-73.6277887933994%2C-69.9609375%5D%2C%5B73.62778879339942%2C470.03906249999994%5D%5D%2C%22overlays%22%3A%5B%22plates%22%5D%2C%22restrictListToMap%22%3A%5B%22restrictListToMap%22%5D%2C%22search%22%3A%22null%2C%22sort%22%3A%22newest%22%2C%22timezone%22%3A%22local%22%2C%22viewModes%22%3A%5B%22map%22%5D%2C%22event%22%3A%22null%7D

Orange are last 24 hrs, yellow last 7 days, white last 30 days]

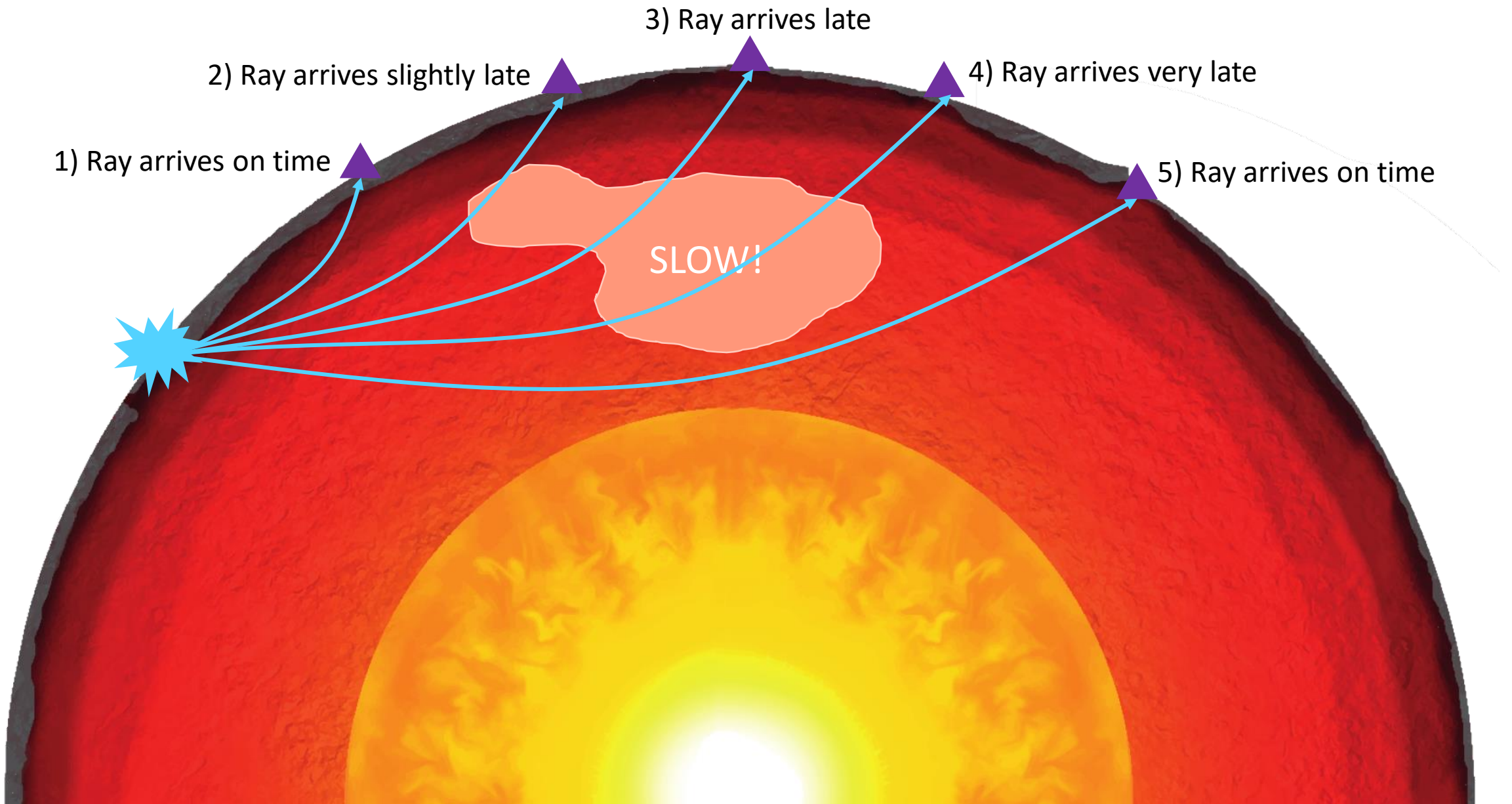
[BEFORE PRESENTING, visit: <https://global.shakemovie.princeton.edu/event.jsp>
. Download an animation of a recent earthquake (especially if it was one that hit the news) or a famous earthquake – I prefer the rotating globe view. Show the video when you get to this slide.

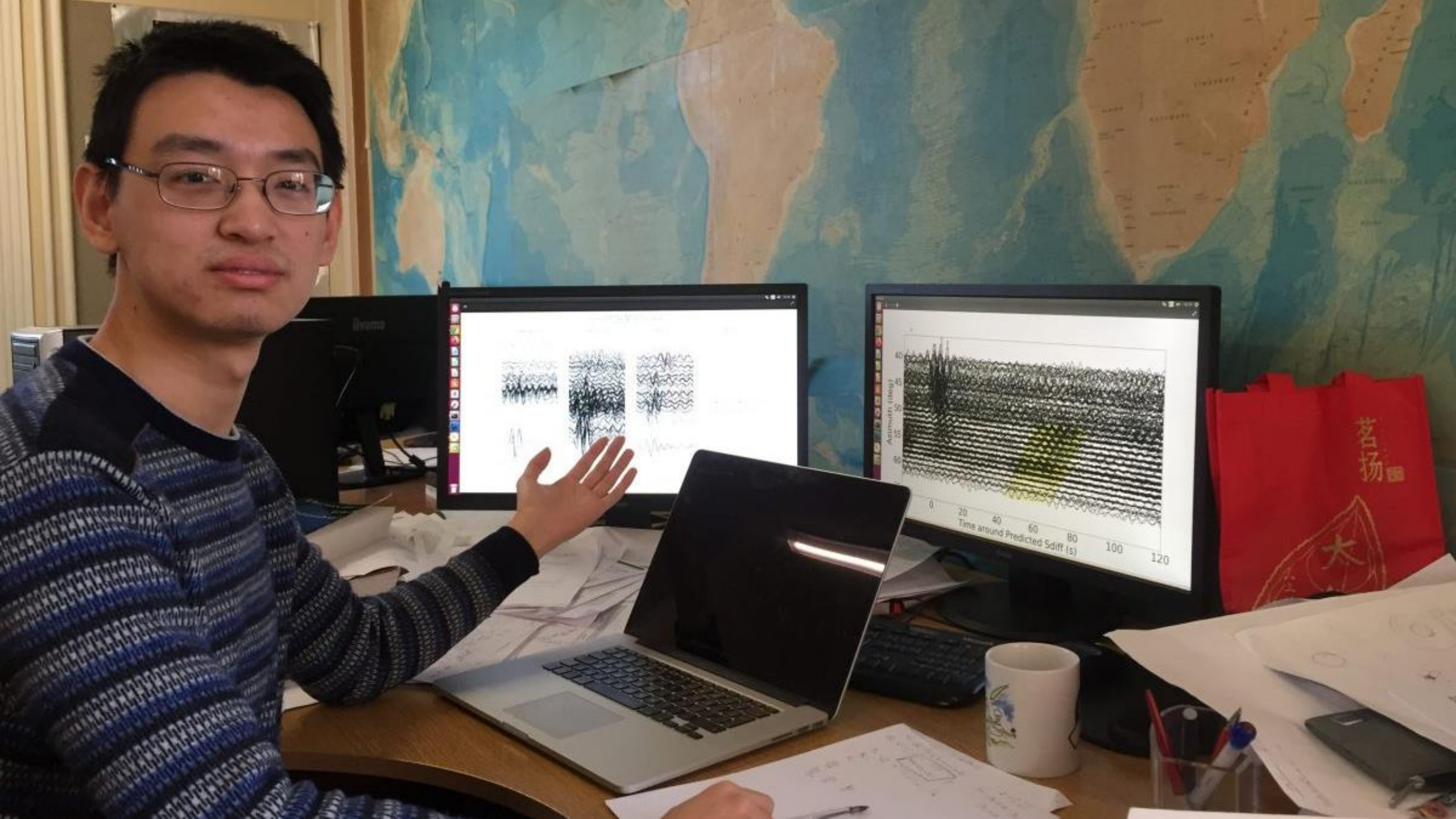


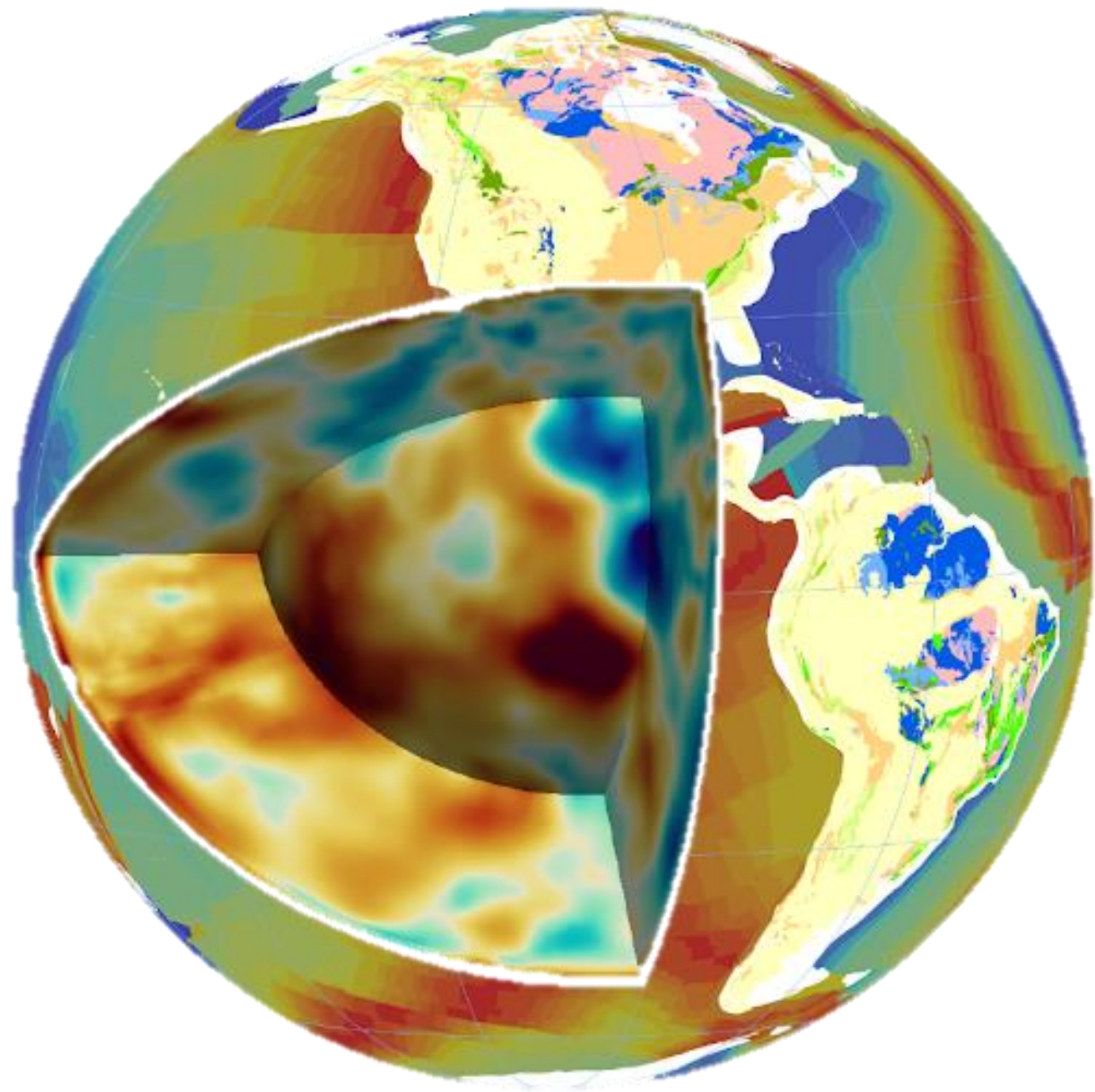
MAKING TOMOGRAPHIC IMAGES

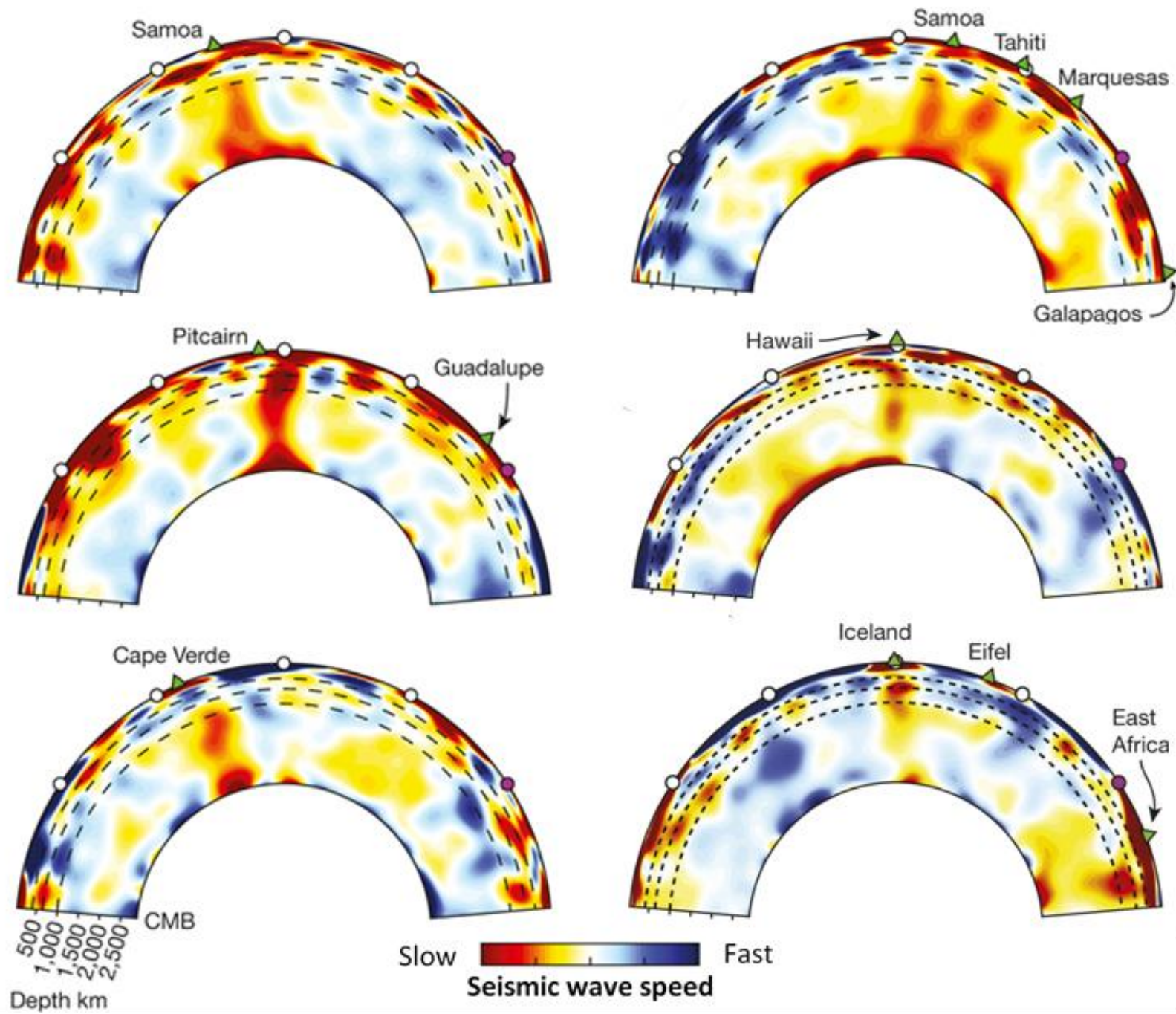
Tomography

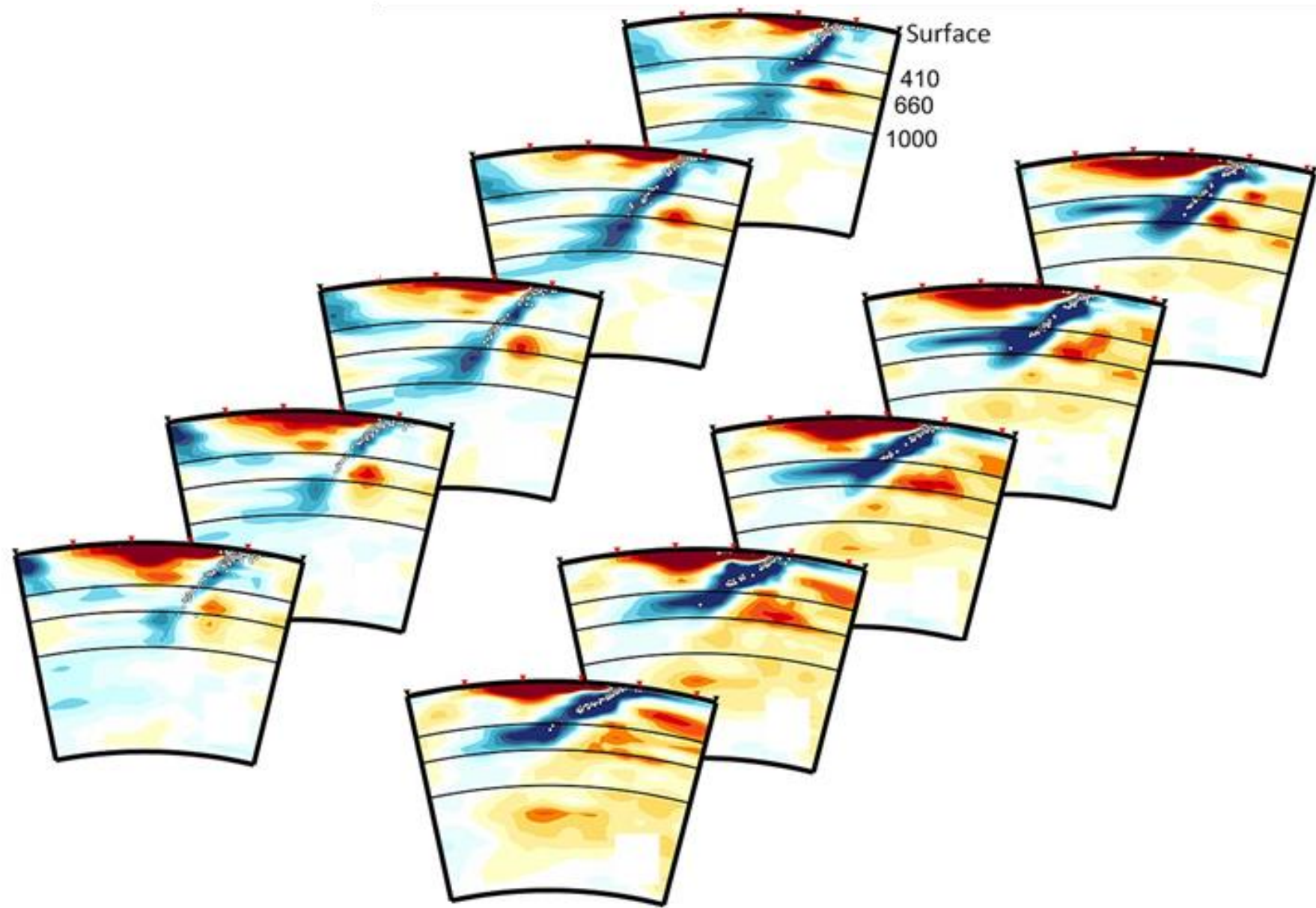
The production of 3D images and 2D slices of the inside of a 3D solid by measuring rays passing through the solid; for example, medical tomography of the body using x-rays or seismic tomography of the Earth using seismic waves.











Slow



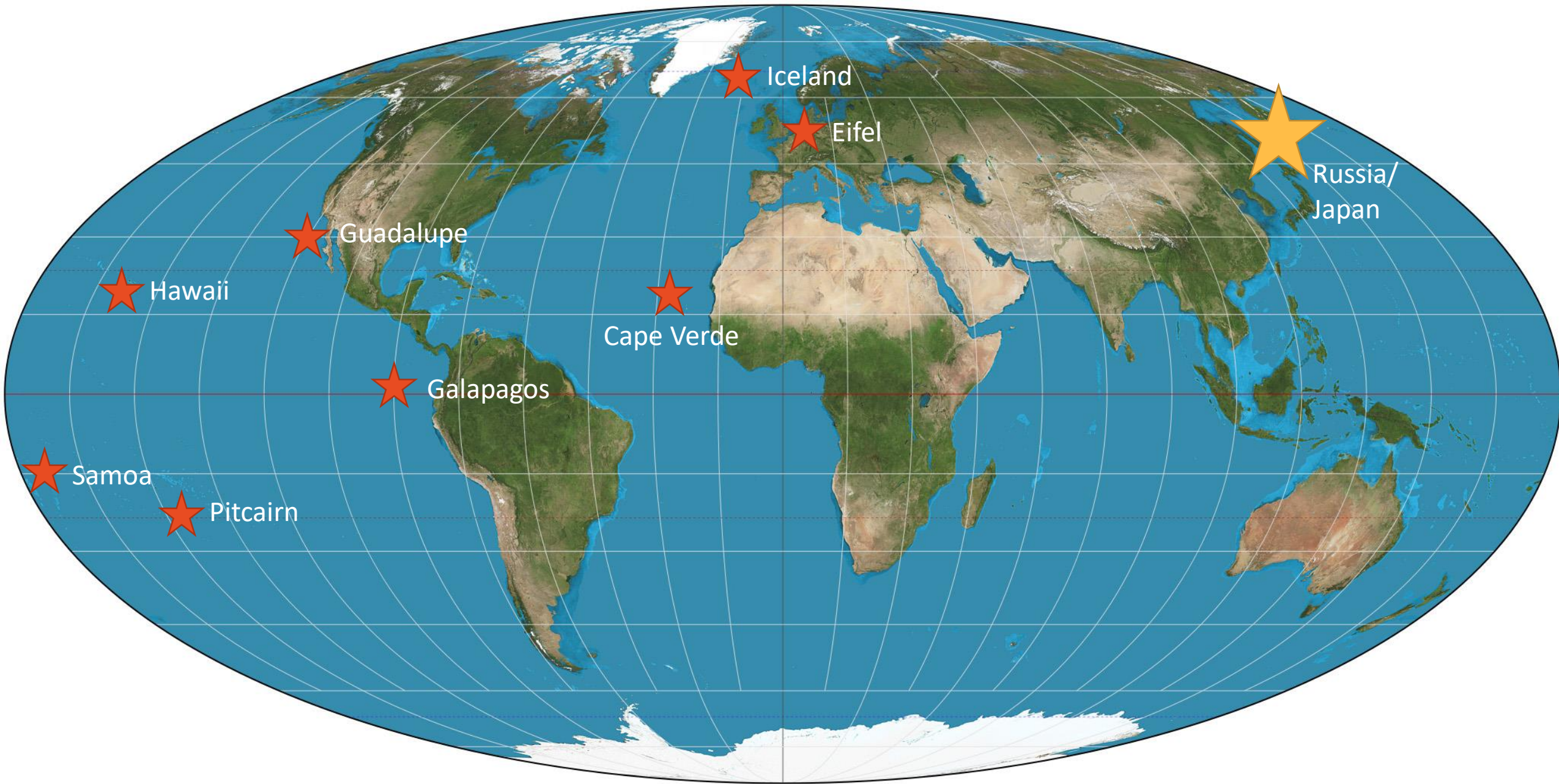
Fast

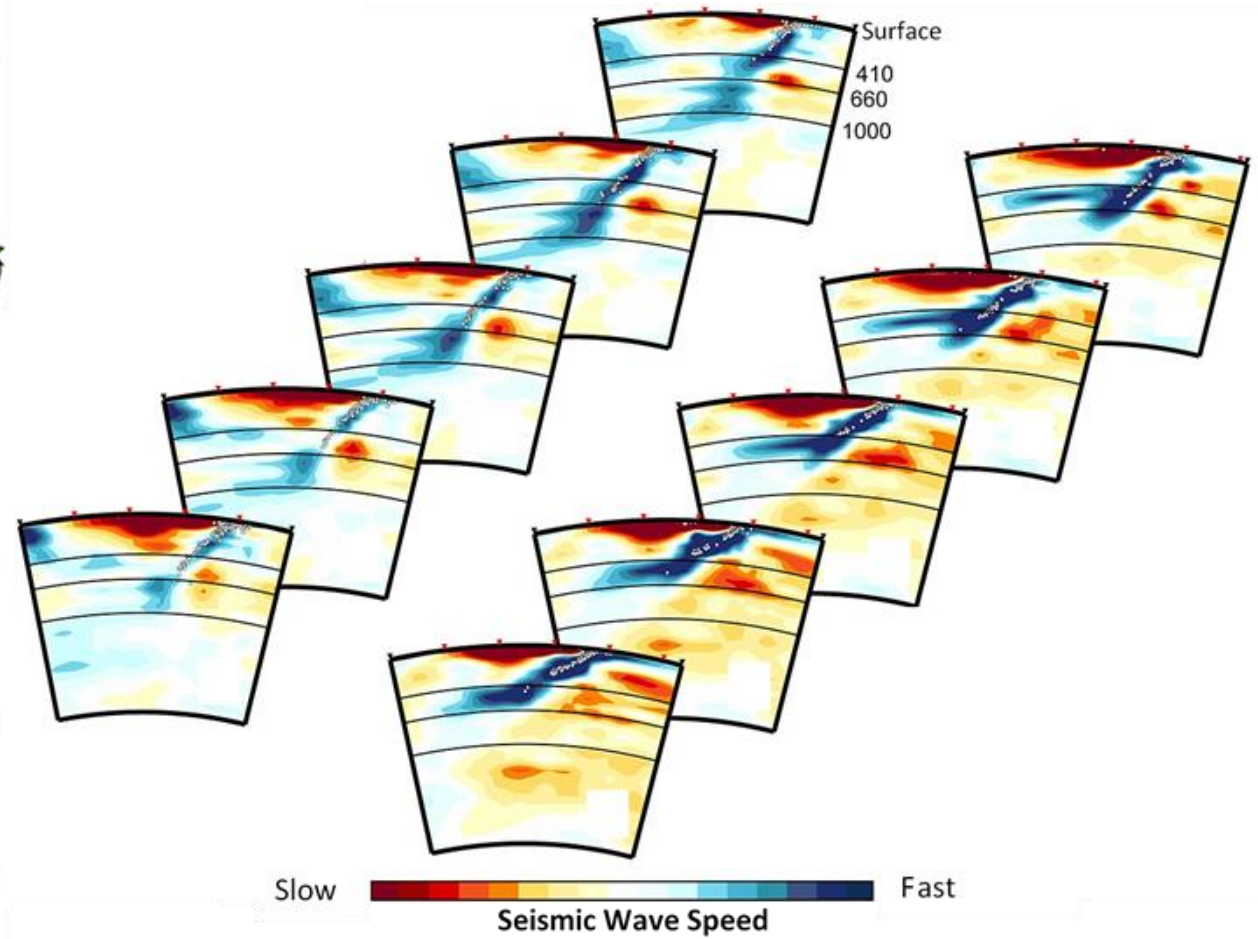
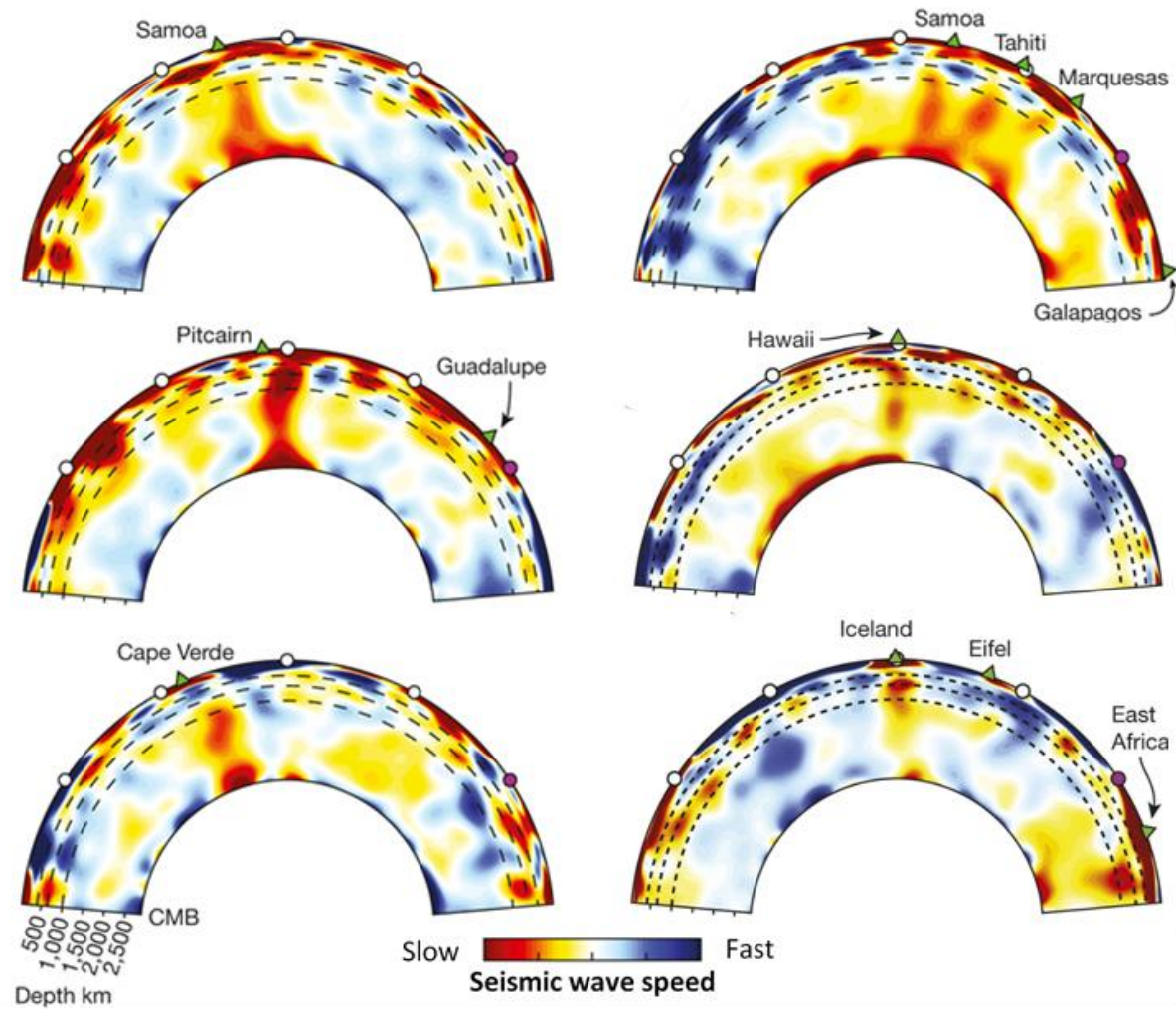
Seismic Wave Speed

A large, irregular red ink splash or blotch serves as the background for the text. The splash is centered and has a textured, painterly appearance with various shades of red and some darker spots. The text is written in a white, hand-drawn, sans-serif font, centered within the red area.

TEMPERATURE AND SEISMIC WAVE SPEED

★ Locations marked on images A ★ Region where images B are from





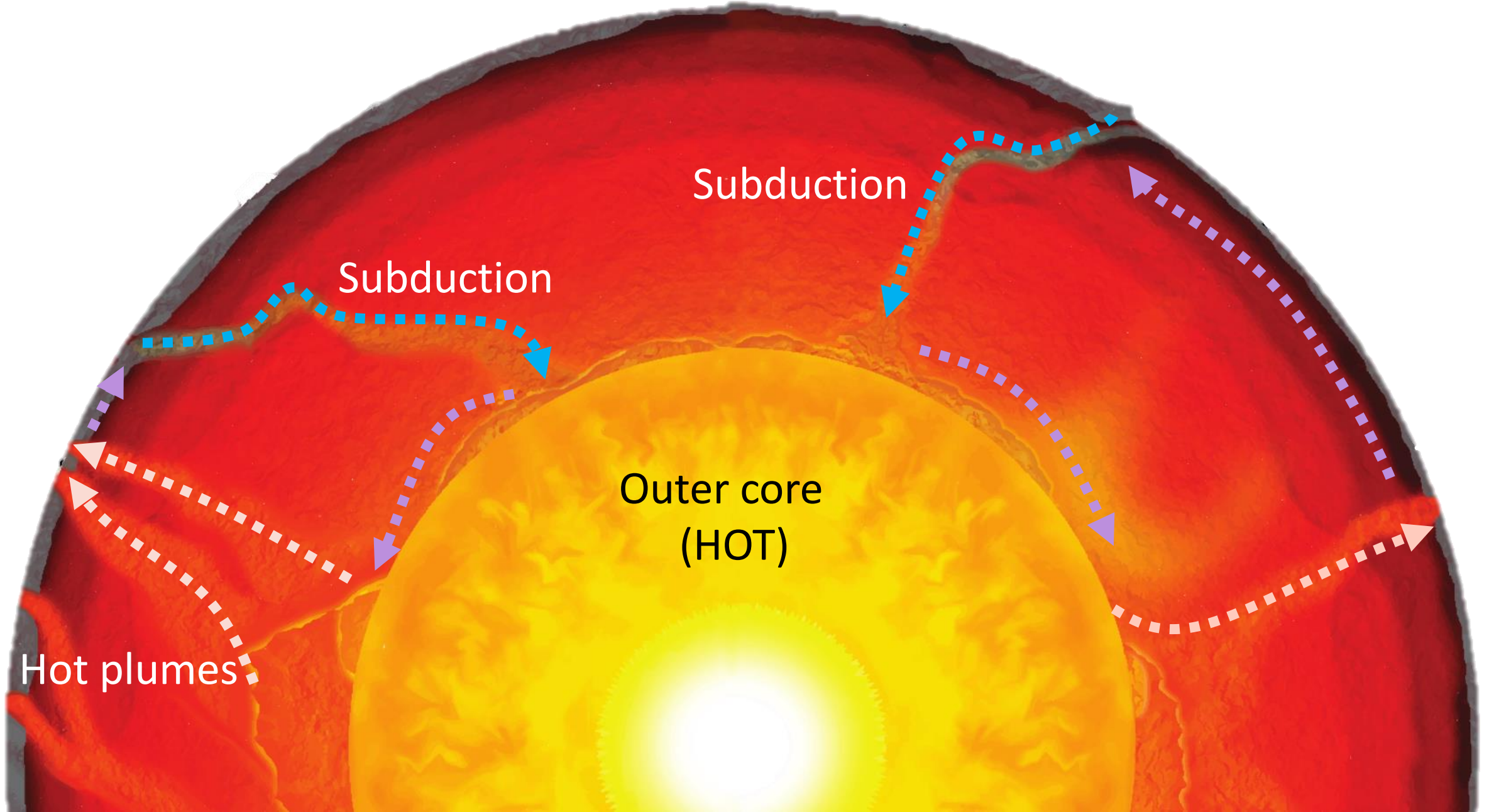
Surface (COLD)

Subduction

Subduction

Outer core
(HOT)

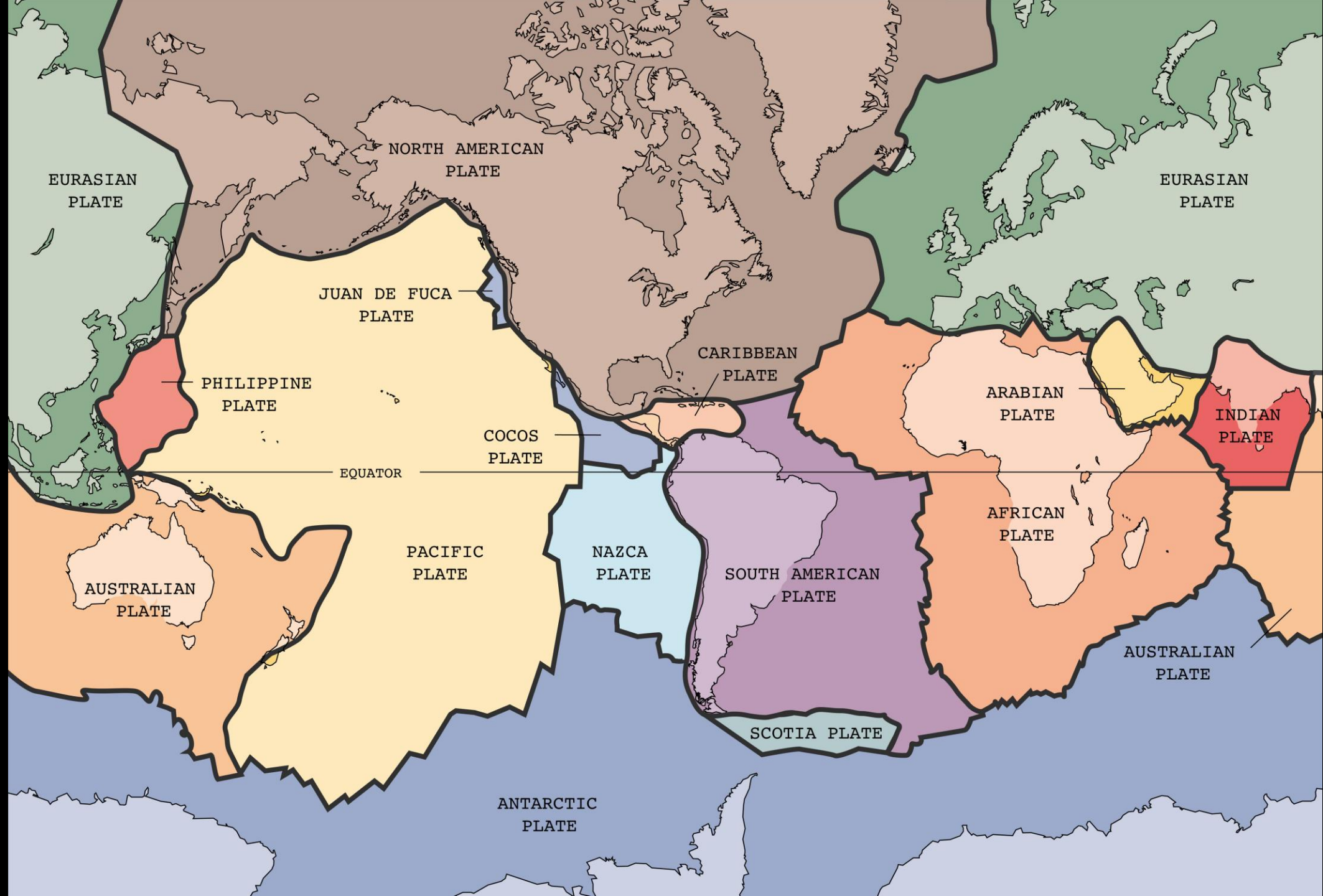
Hot plumes

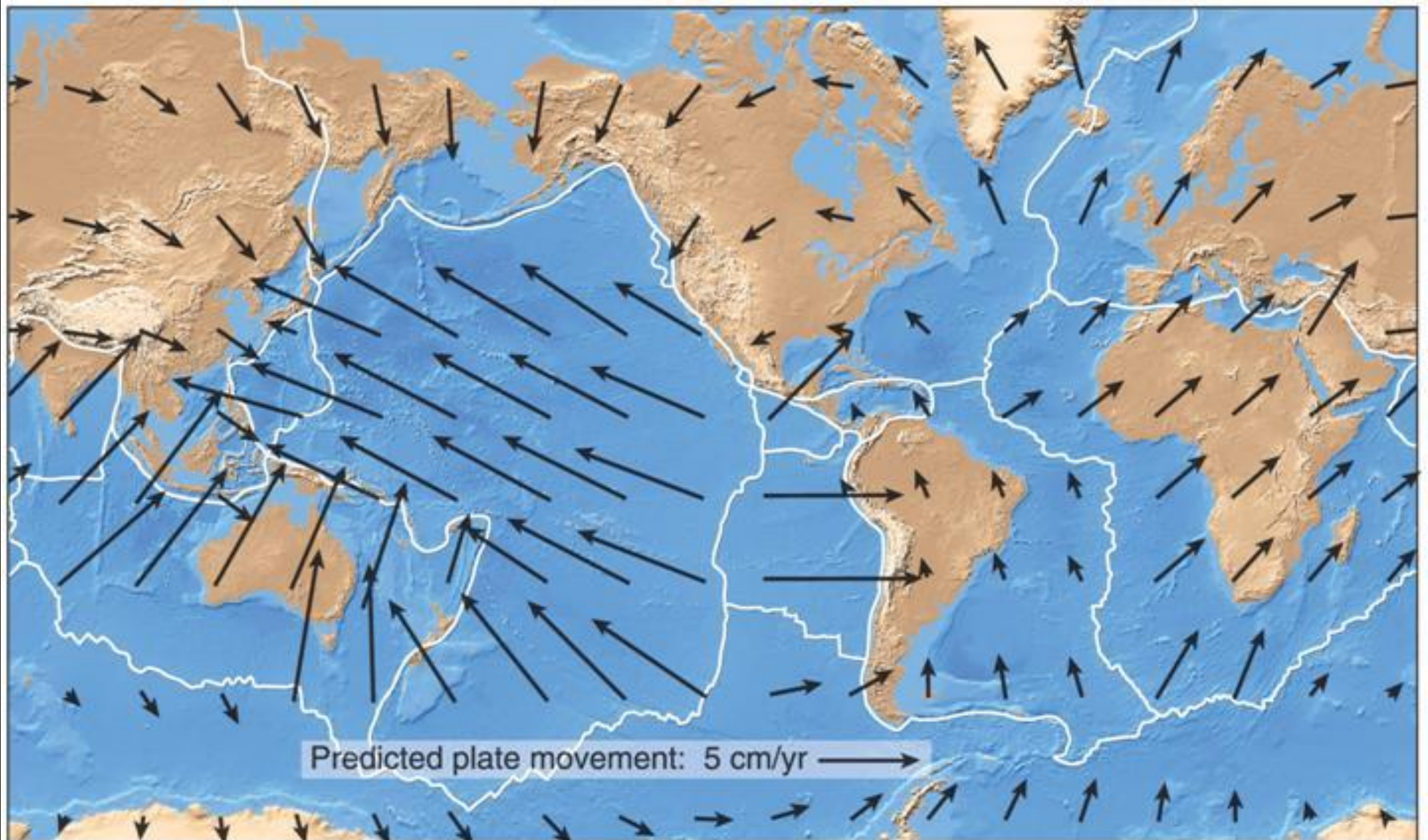


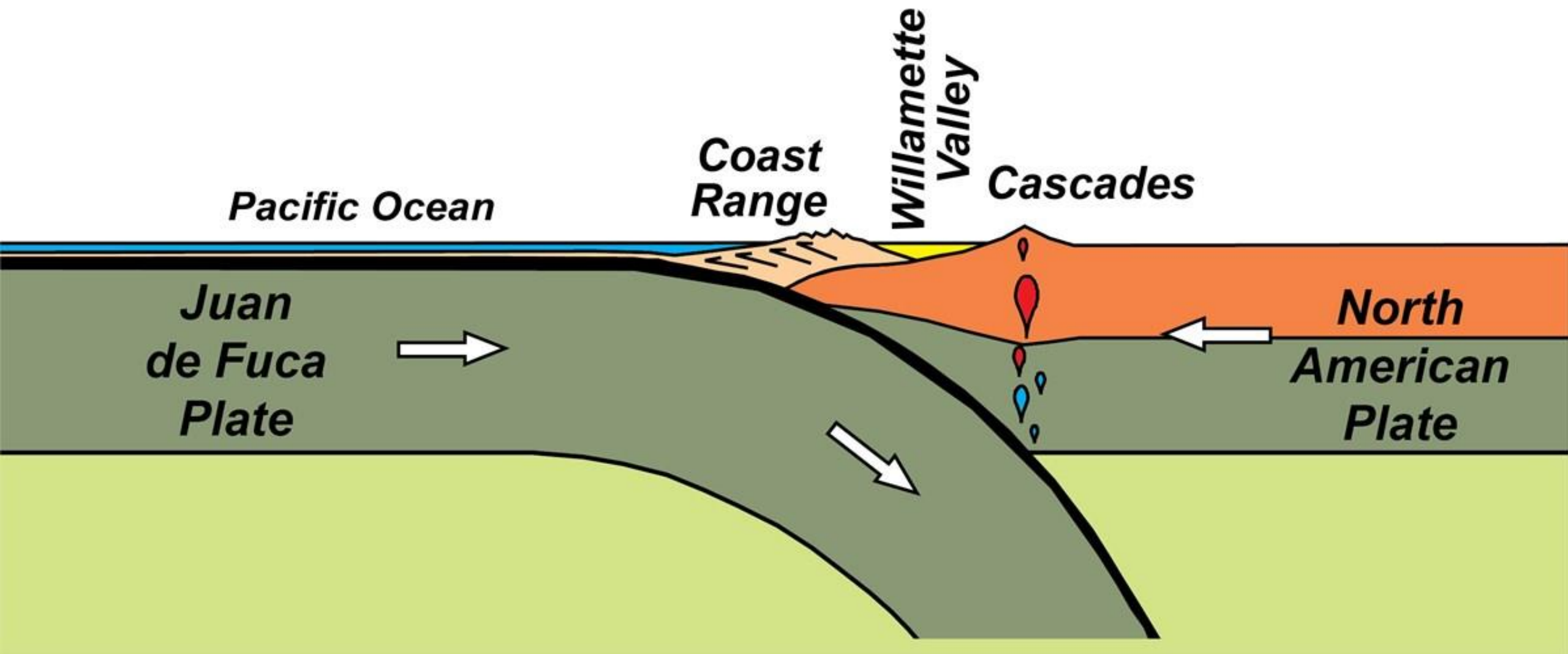
Mantle plume

An area of hotter than usual mantle which rises upwards towards the top of the mantle. This movement upwards of hot mantle is part of the convection of the mantle.



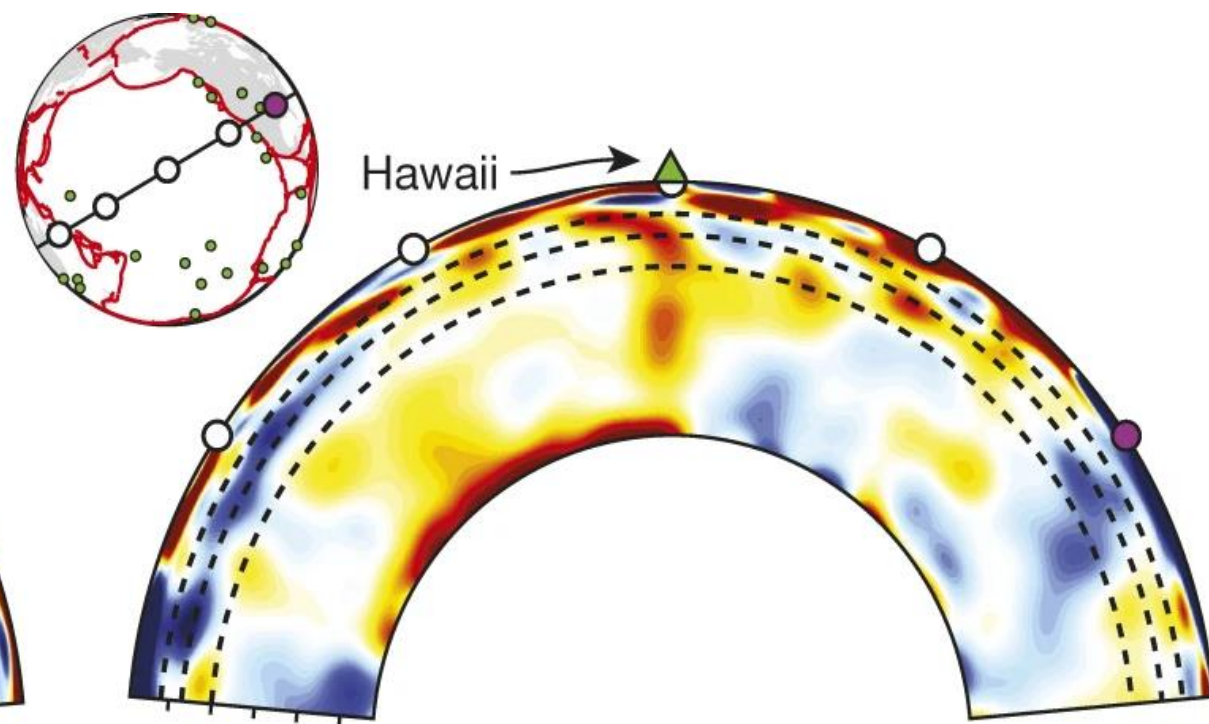
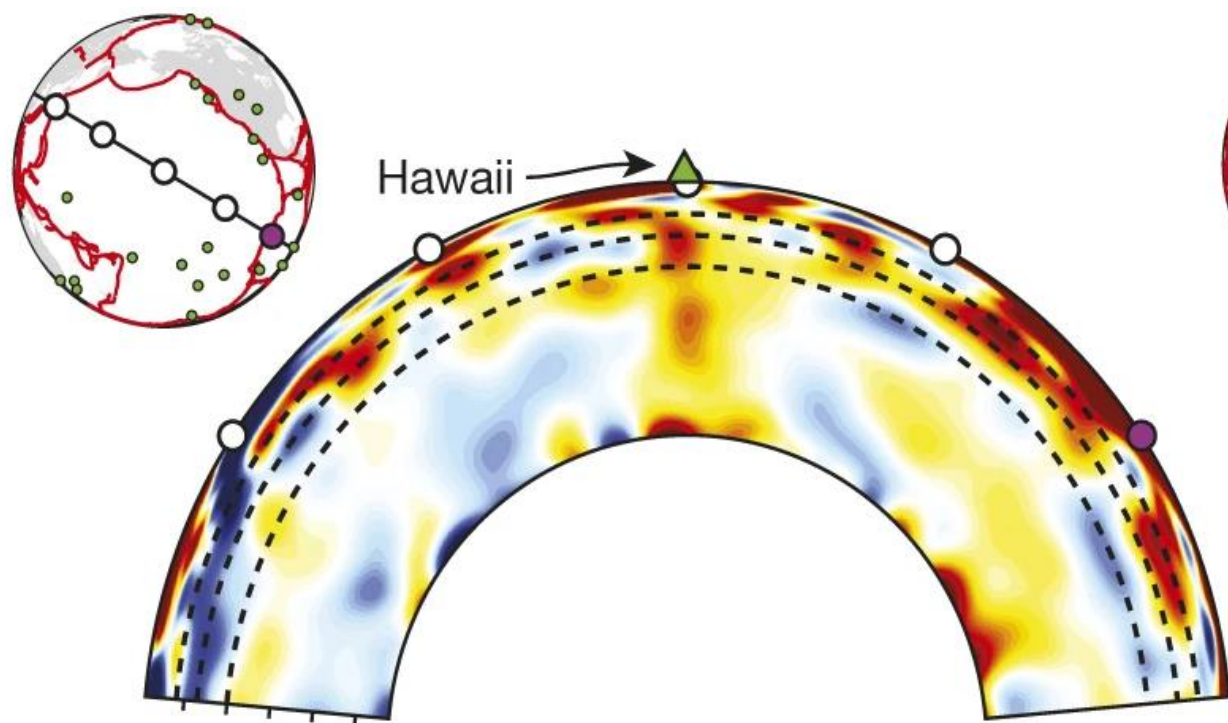






Subduction

The downwards movement of a cold plate of the Earth's crust and upper mantle into the warmer mantle, below another plate. The movement of the cold mantle and crust downwards is part of the convection of the mantle.



Video:

<https://www.youtube.com/watch?v=888nbjvKNts>

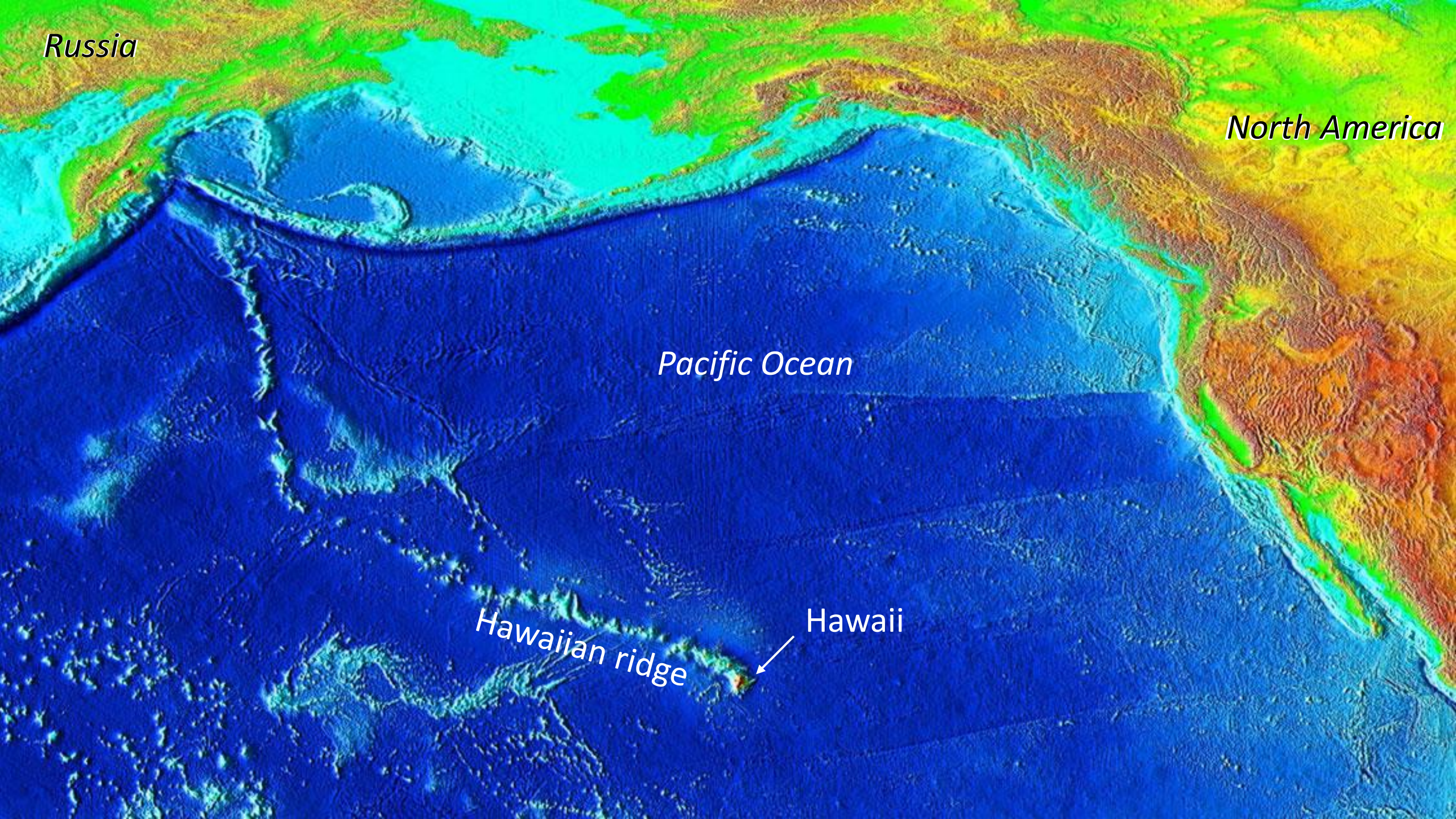
Russia

North America

Pacific Ocean

Hawaiian ridge

Hawaii





MAKING HOTSPOT TRACKS



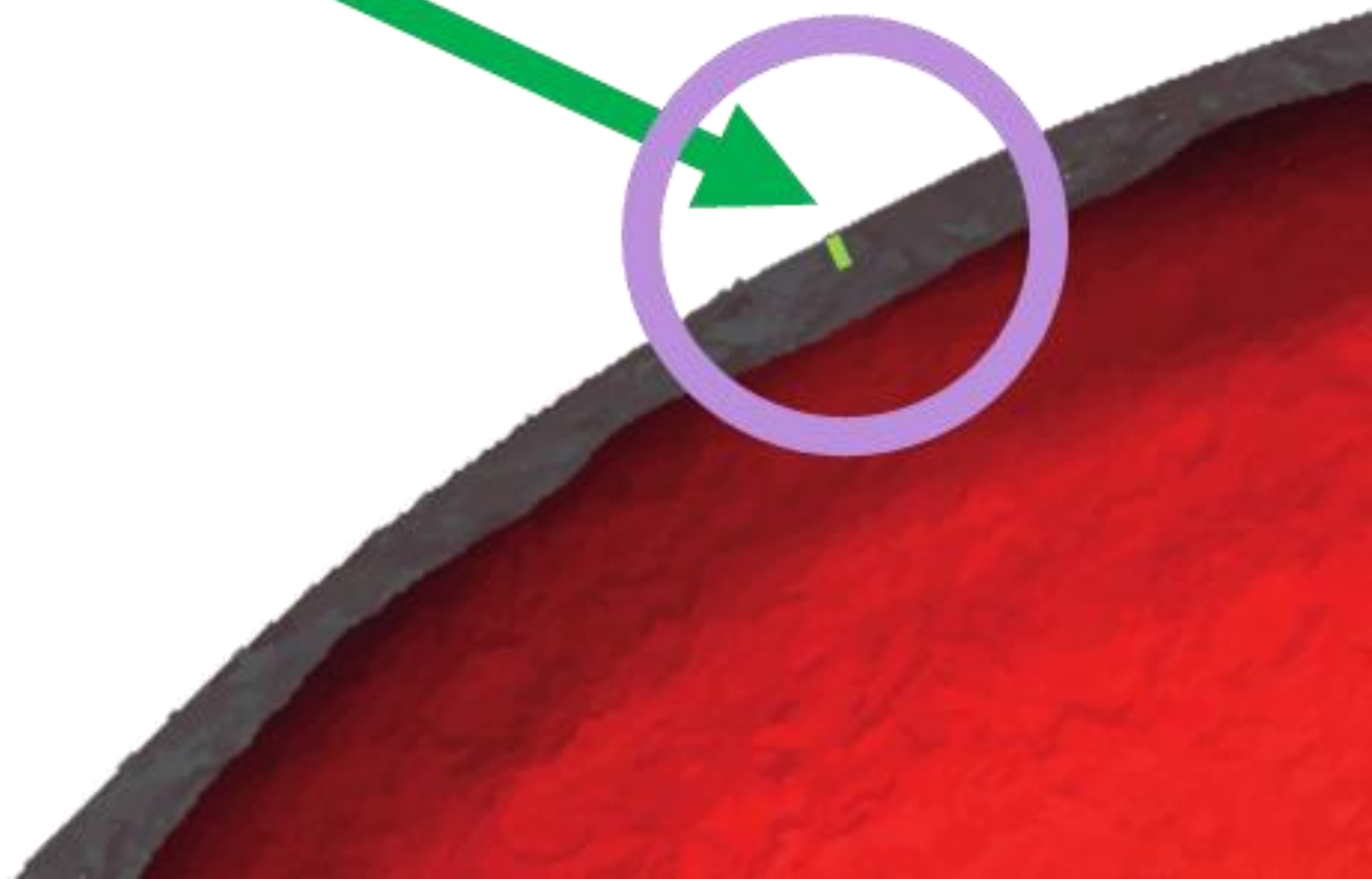
SO, WHAT IS THE
MANTLE LIKE ON
THE INSIDE?



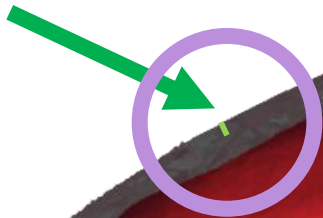
Peridotite

The (solid) green rock which makes up the Earth's mantle. It is made of crystals of the minerals Olivine and Pyroxene.

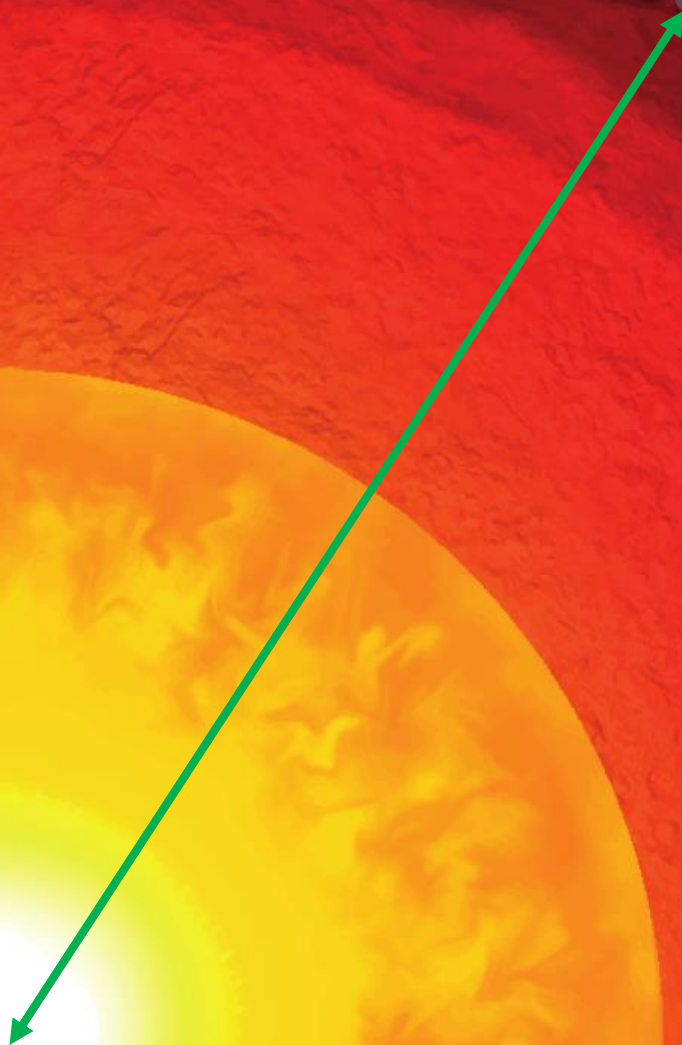
Kola Superdeep
borehole (12km)



Kola Superdeep
borehole (12km)



Radius of the Earth
(~6,371 km)





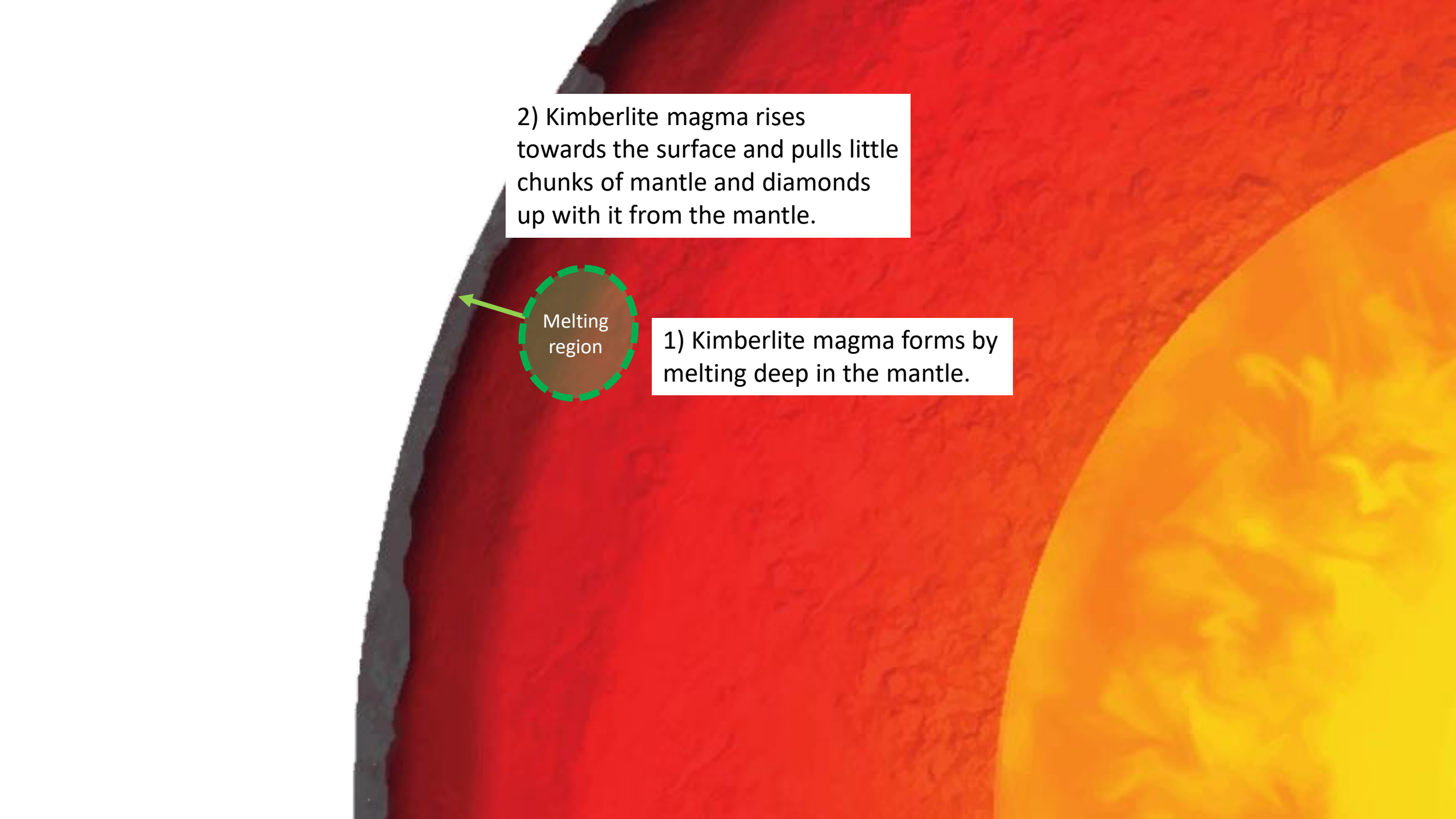






Melting
region

1) Kimberlite magma forms by melting deep in the mantle.



2) Kimberlite magma rises towards the surface and pulls little chunks of mantle and diamonds up with it from the mantle.

Melting
region

1) Kimberlite magma forms by melting deep in the mantle.

3) Kimberlite magma erupts, bringing diamonds and peridotite to the surface



2) Kimberlite magma rises towards the surface and pulls little chunks of mantle and diamonds up with it from the mantle.



1) Kimberlite magma forms by melting deep in the mantle.



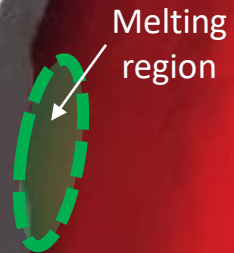
3) Kimberlite magma erupts, bringing diamonds and peridotite to the surface



2) Kimberlite magma rises towards the surface and pulls little chunks of mantle and diamonds up with it from the mantle.



1) Kimberlite magma forms by melting deep in the mantle.



Ordinary magma forms by melting at the top of the mantle.

3) Kimberlite magma erupts, bringing diamonds and peridotite to the surface

2) Kimberlite magma rises towards the surface and pulls little chunks of mantle and diamonds up with it from the mantle.

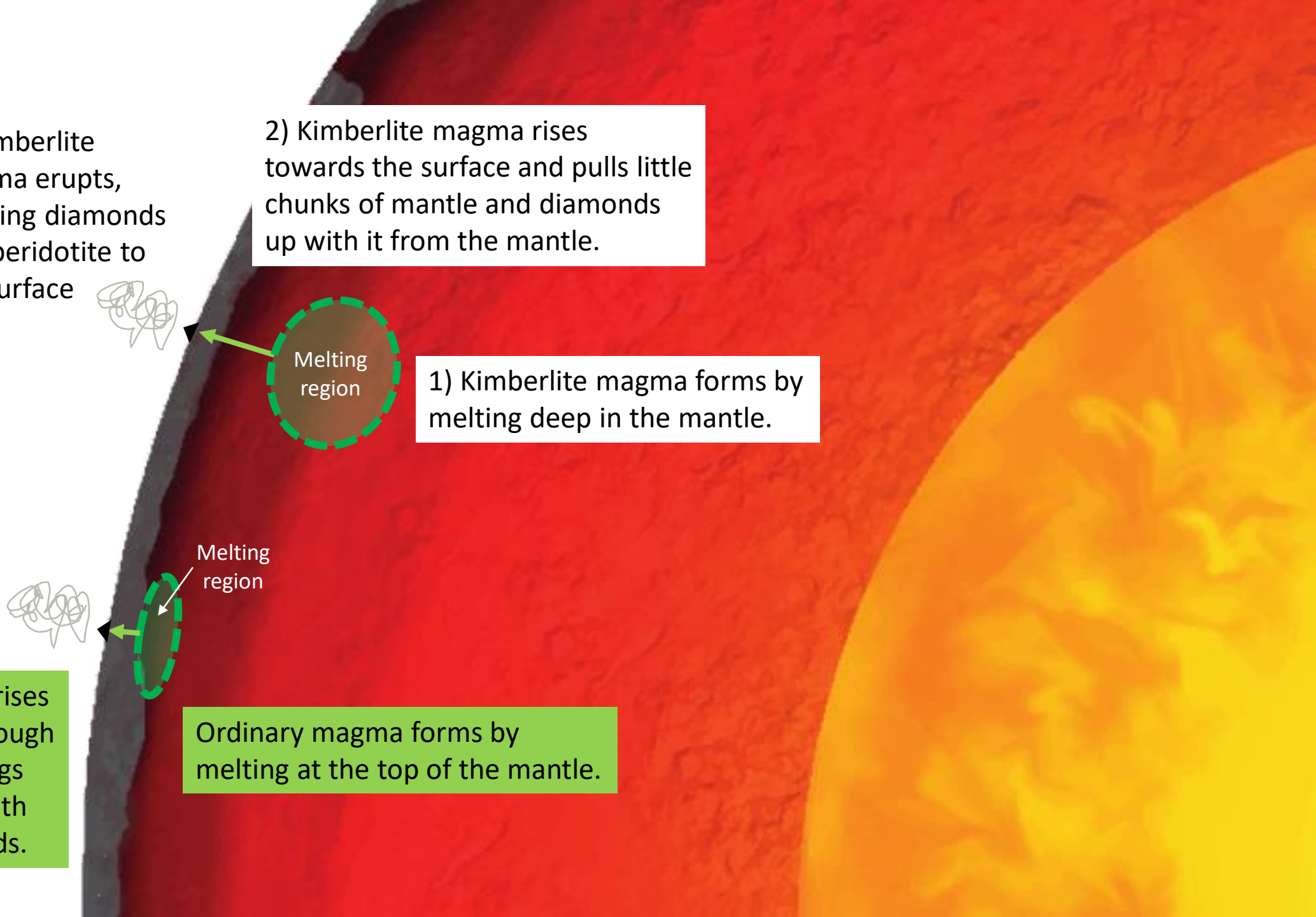
1) Kimberlite magma forms by melting deep in the mantle.

Melting region

Melting region

Ordinary magma rises to the surface through the crust and brings chunks of crust with it, but no diamonds.

Ordinary magma forms by melting at the top of the mantle.

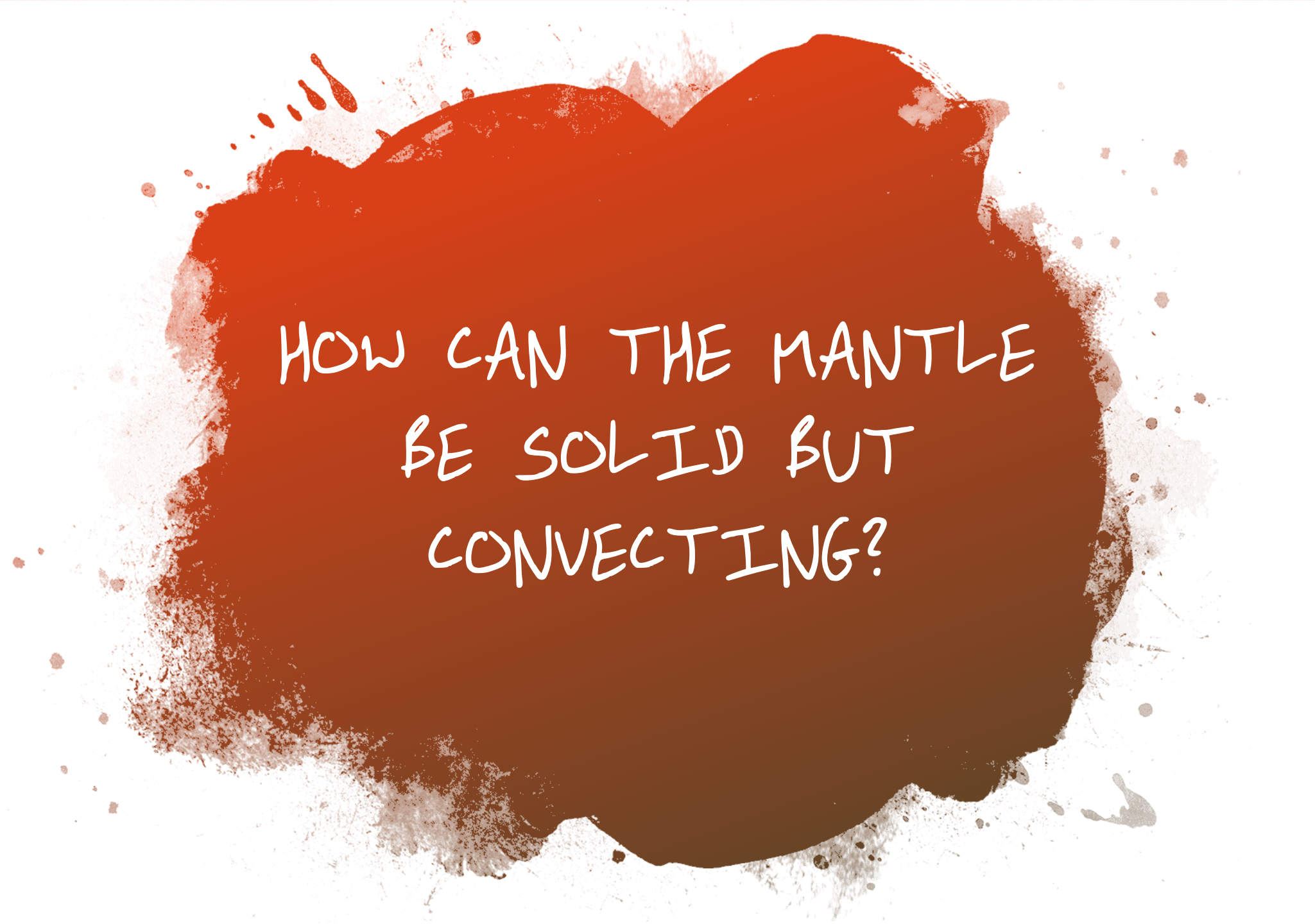


Kimberlite pipe

A volcano with a magma source from melting deep in the mantle. They frequently bring up pieces of peridotite in their magma, and are famous for being where diamonds are found in the Earth's crust.

The mantle is SOLID

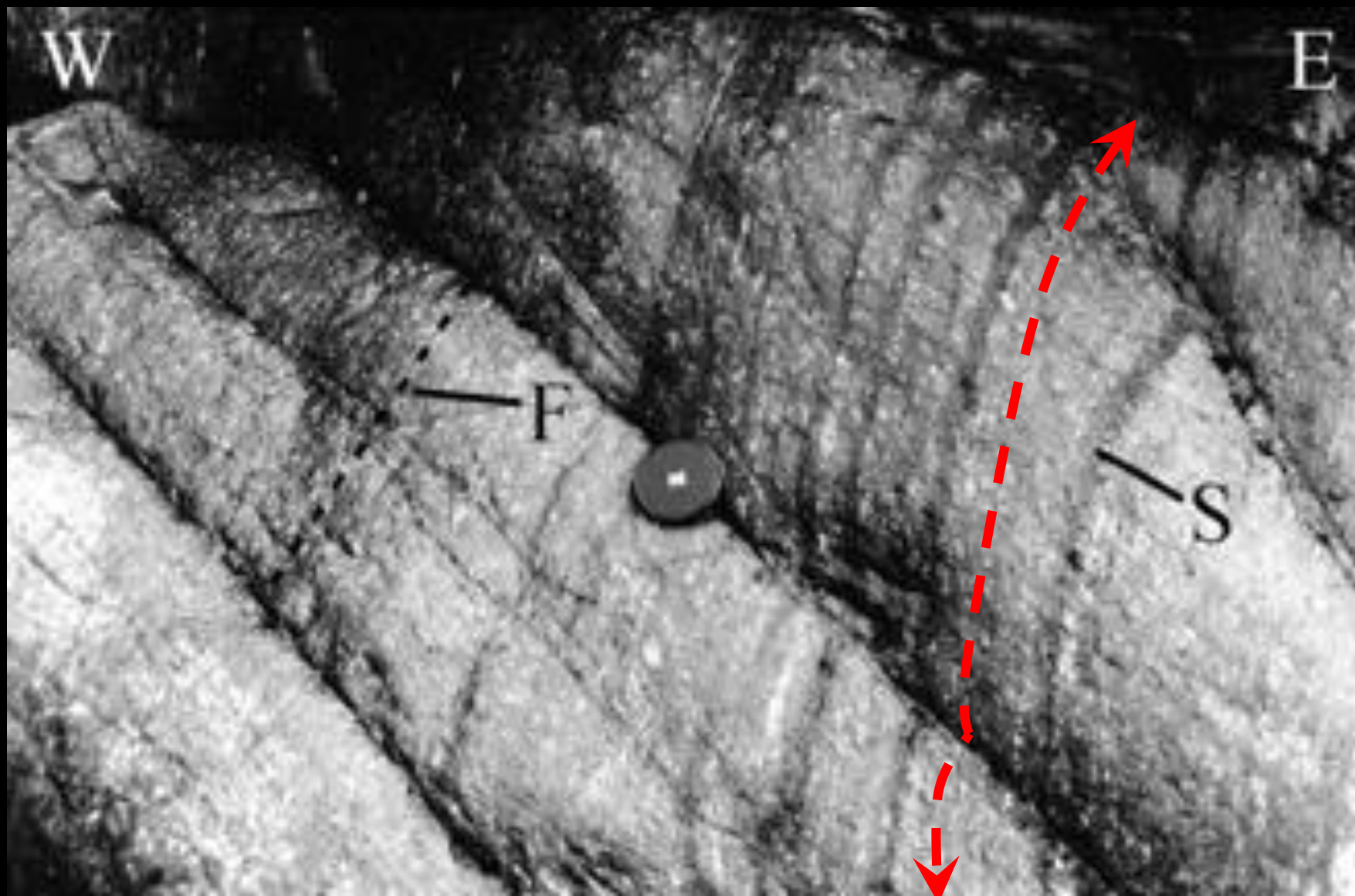


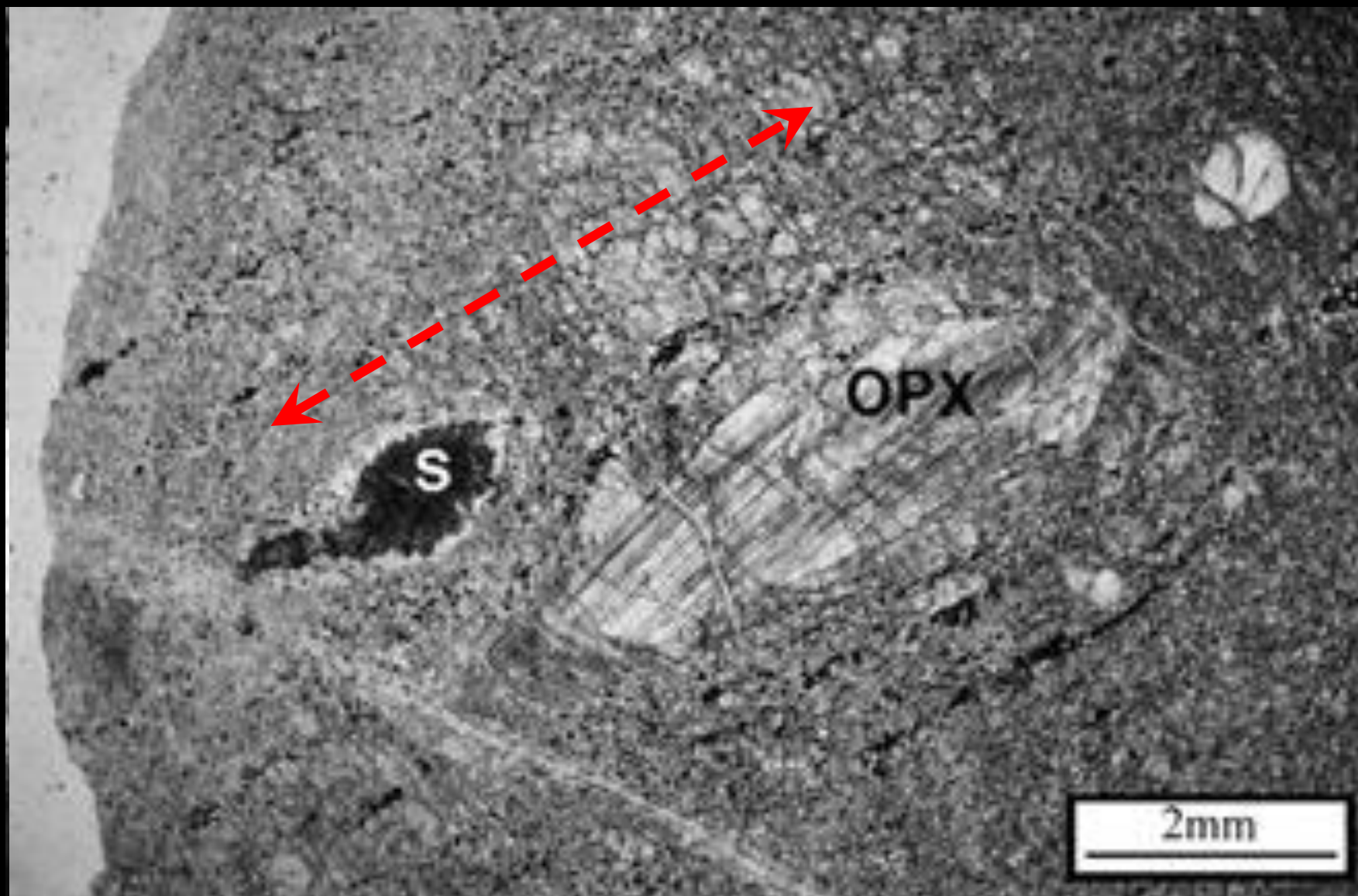


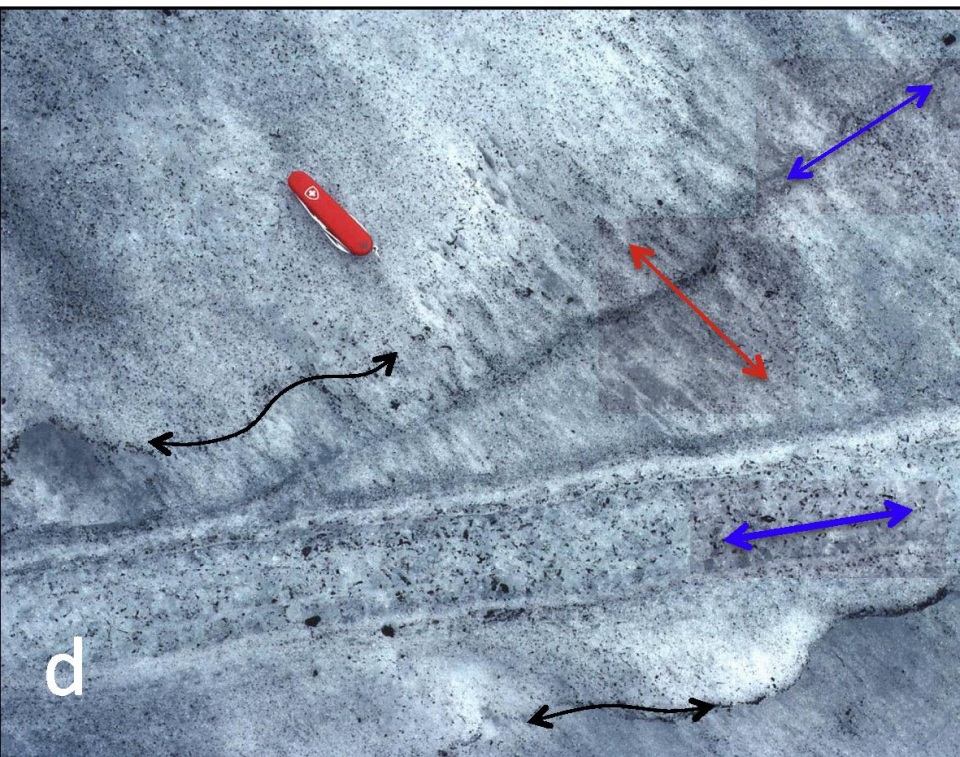
HOW CAN THE MANTLE
BE SOLID BUT
CONVECTING?

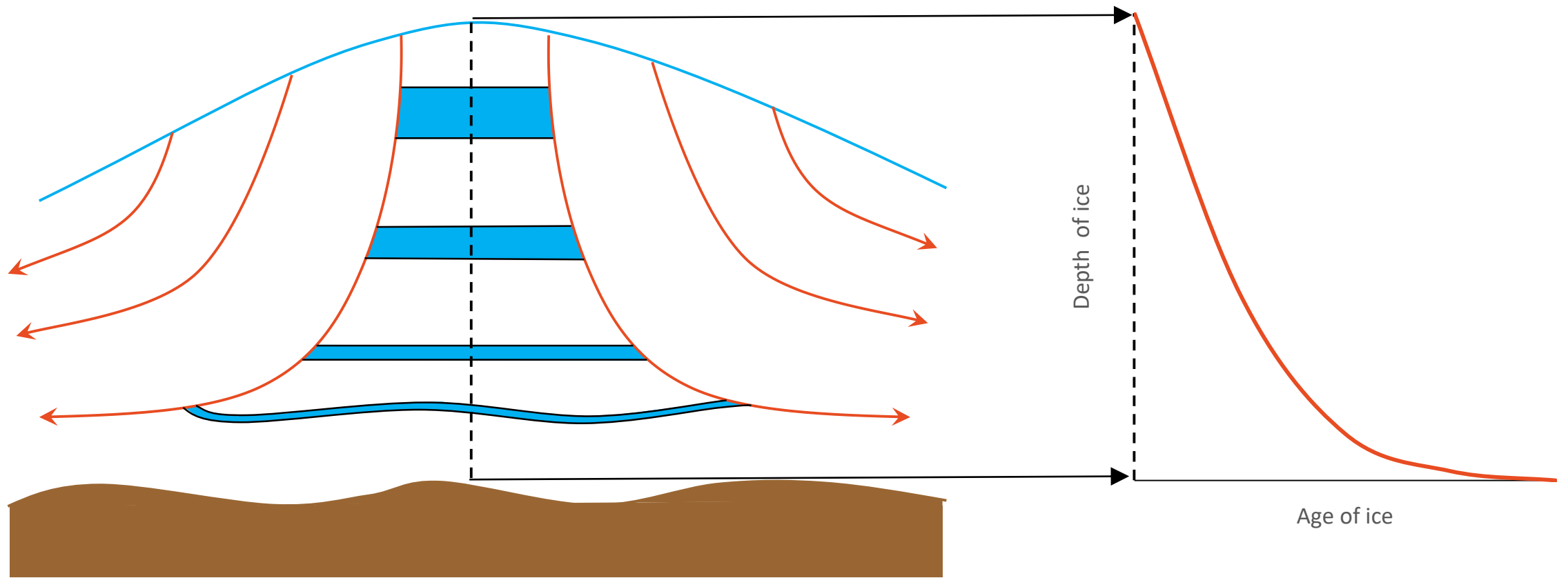
Creep

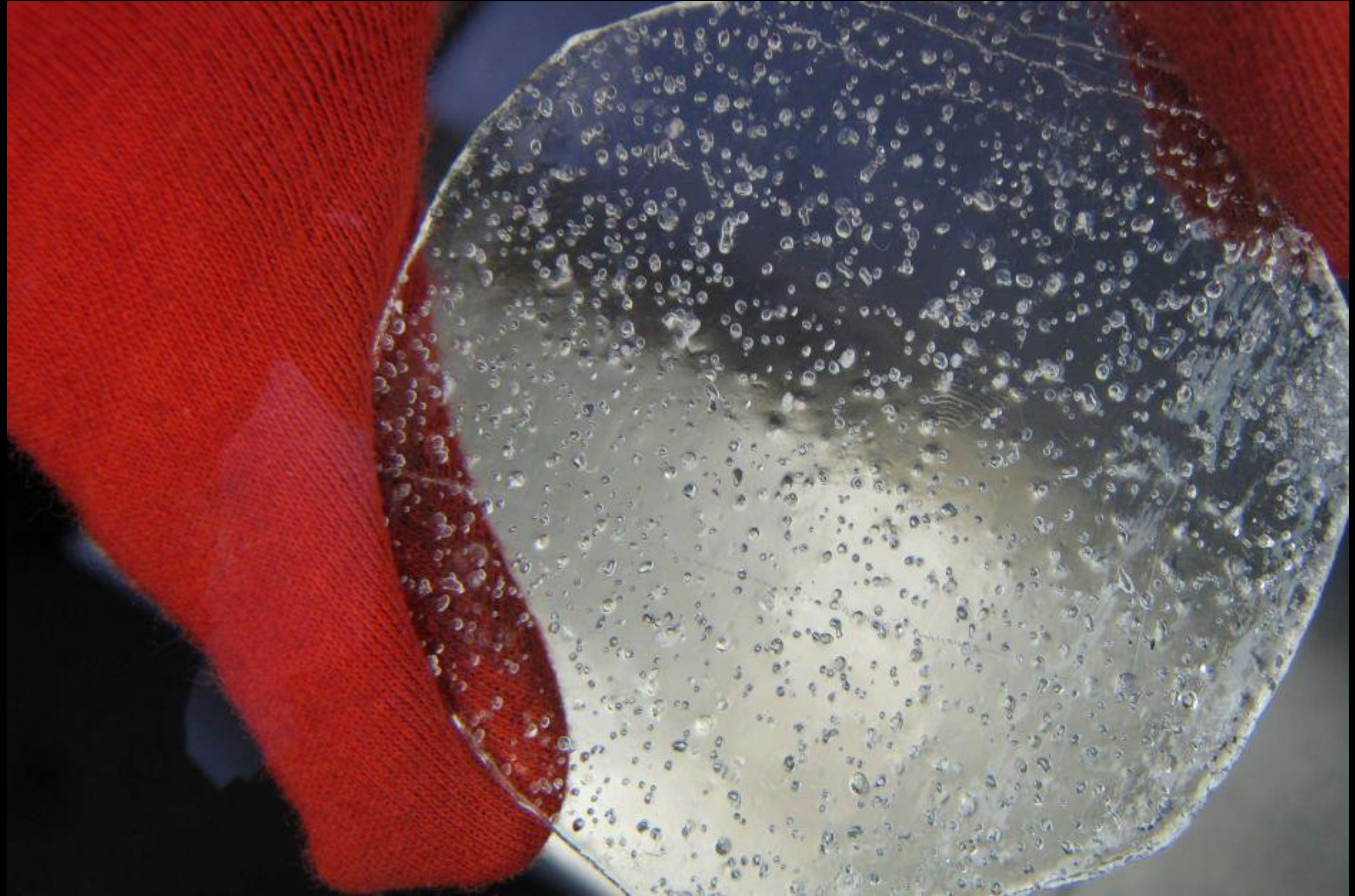
The gradual flow of solids, caused by the addition of many tiny movements of the particles which make up the solid, for example crystals sliding past each other, or dissolving and re-crystallising.













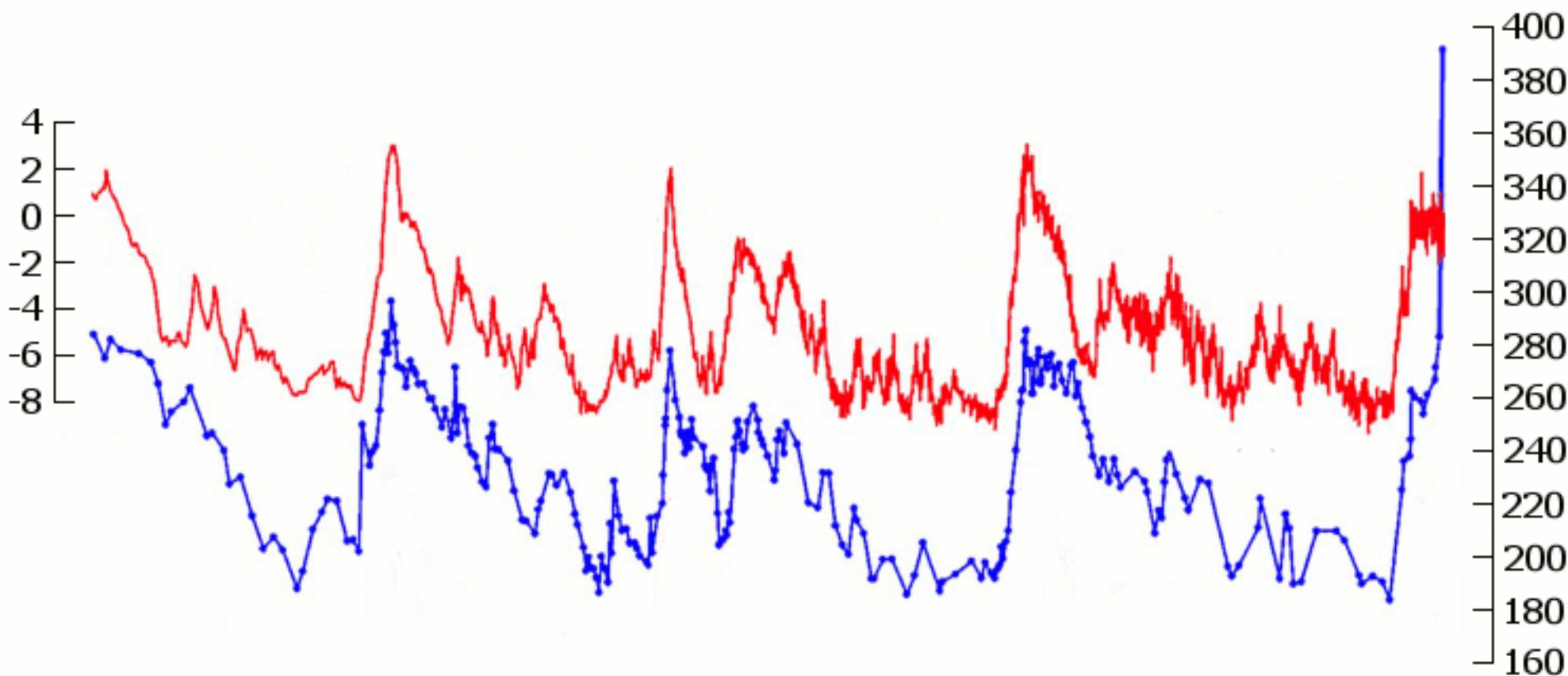
The Vostok (Antarctica) Ice Core Record.

Carbon Dioxide versus Temperature for the last 420,000 years.

Depth of Ice (metres)

3300 3200 3000 2750 2500 2000 1500 1000 500 0

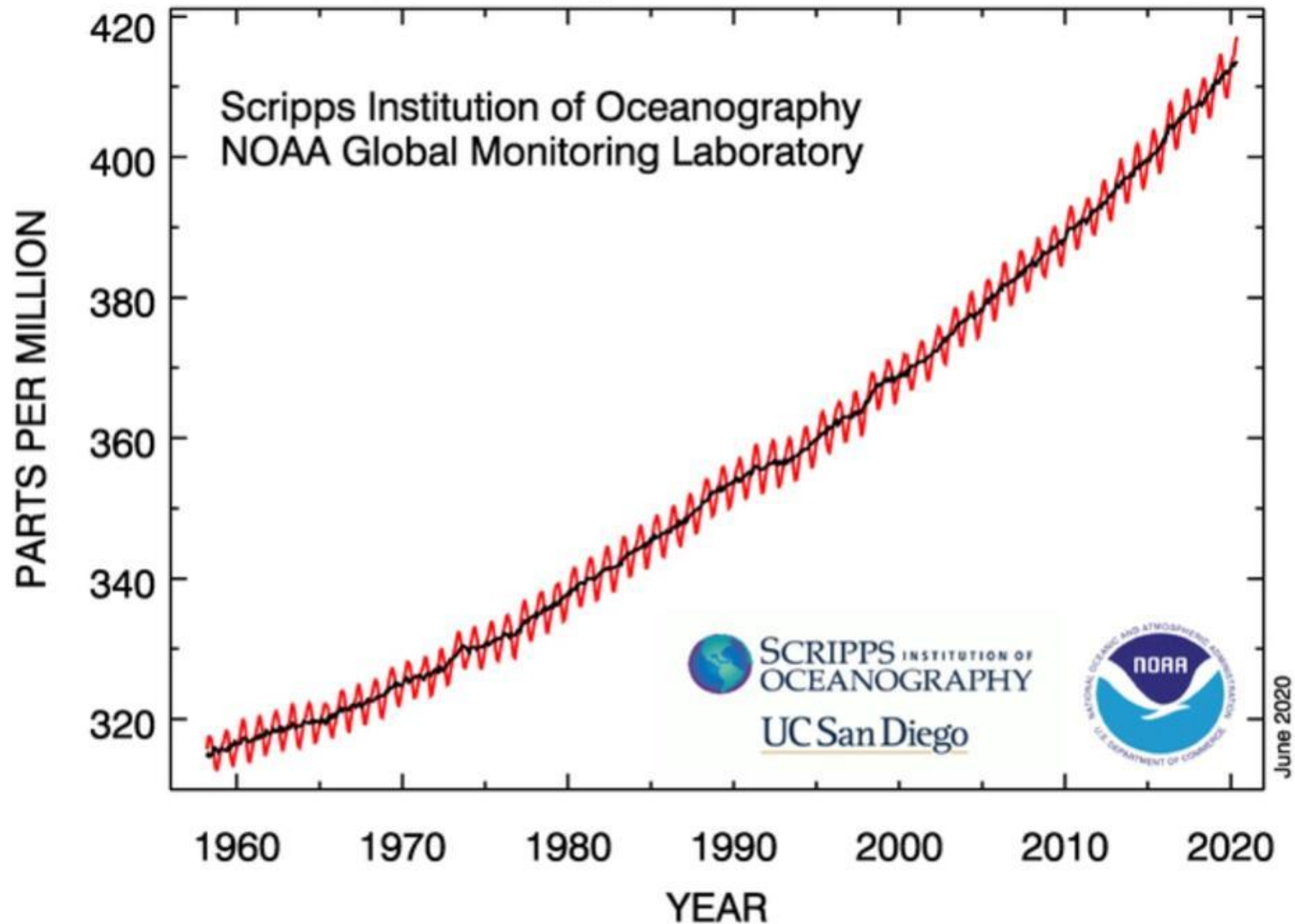
Temperature difference from 1961 to 1990
average of -56 (in degrees centigrade)



Carbon Dioxide (parts per million (by volume))

Age (years before present)

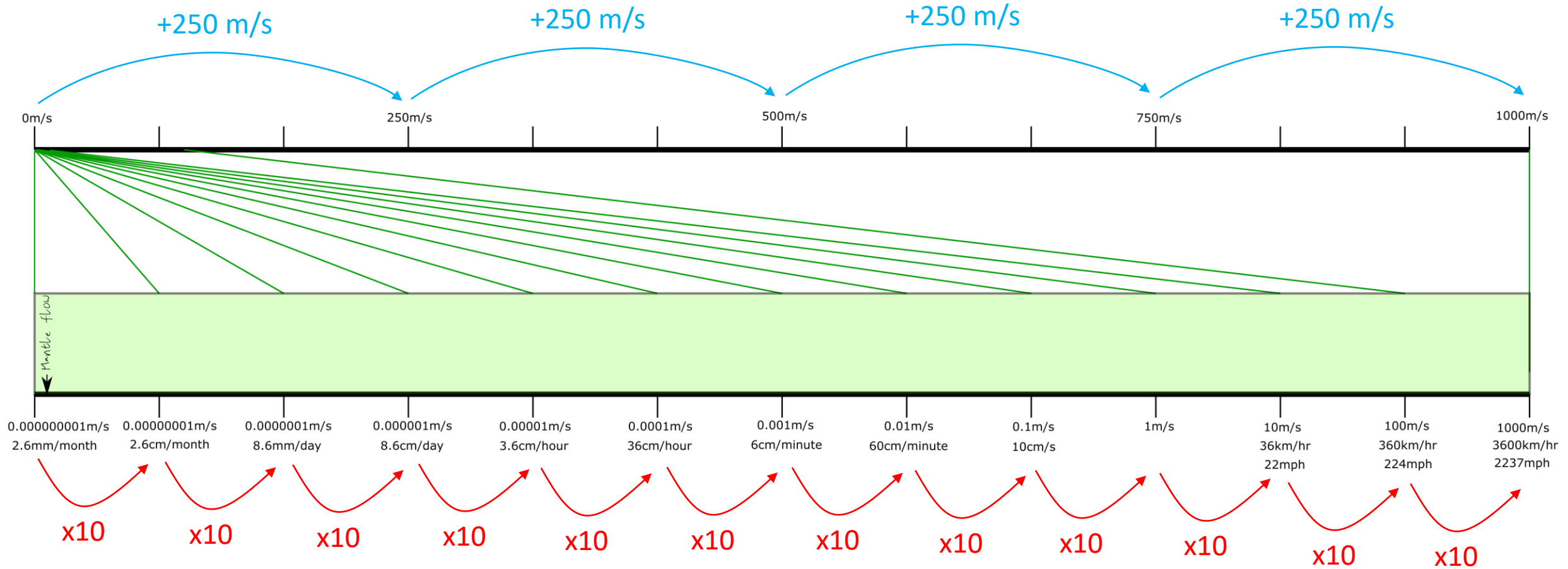
Atmospheric CO₂ at Mauna Loa Observatory



A dark, textured, cloud-like shape with a white background and scattered dark specks. The shape is irregular and has a rough, splattered appearance. The text "BUT HOW SLOW?" is written in white, handwritten-style capital letters across the center of the dark shape.

BUT HOW SLOW?

Linear Scale



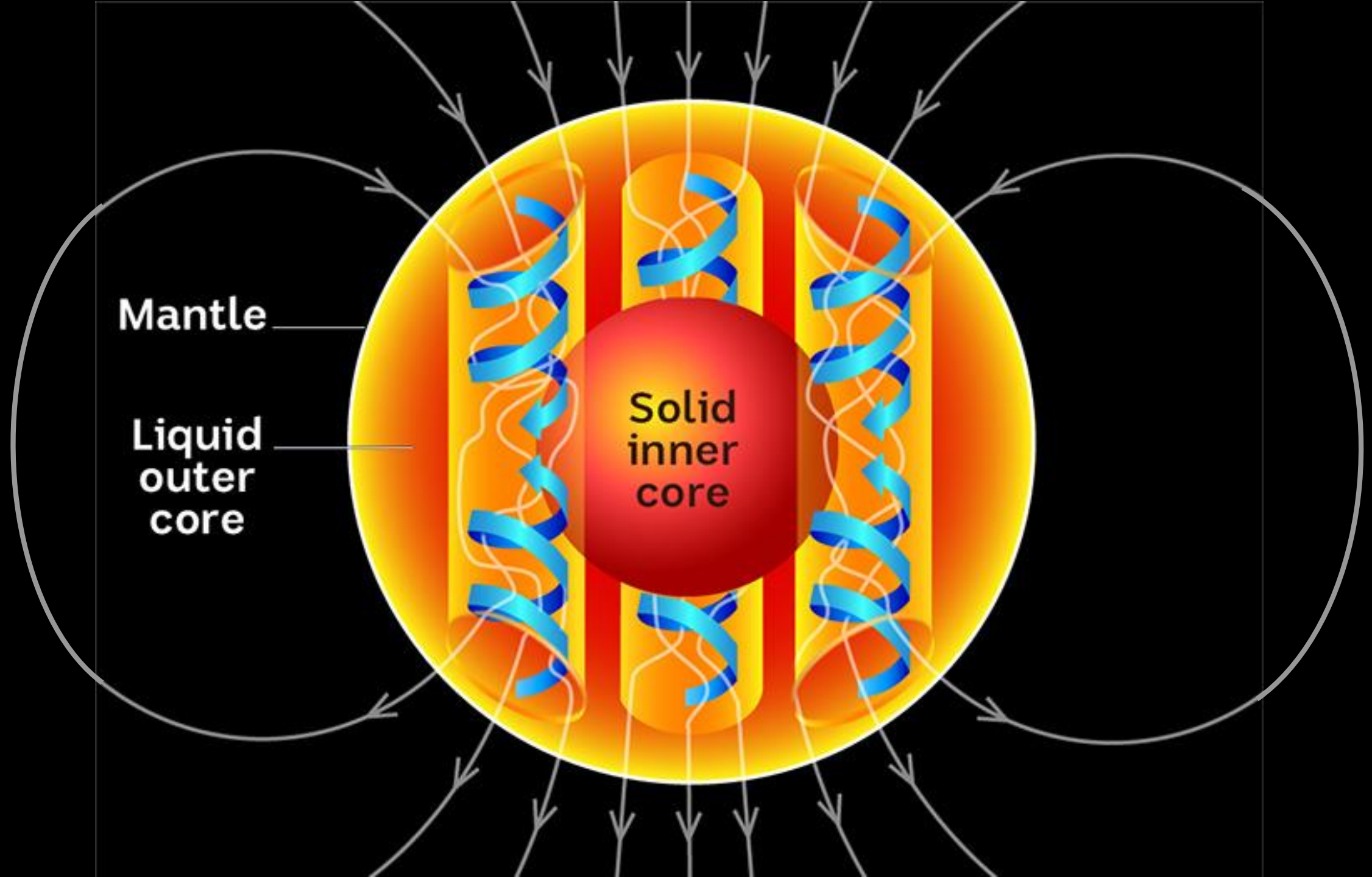
Logarithmic Scale

Linear

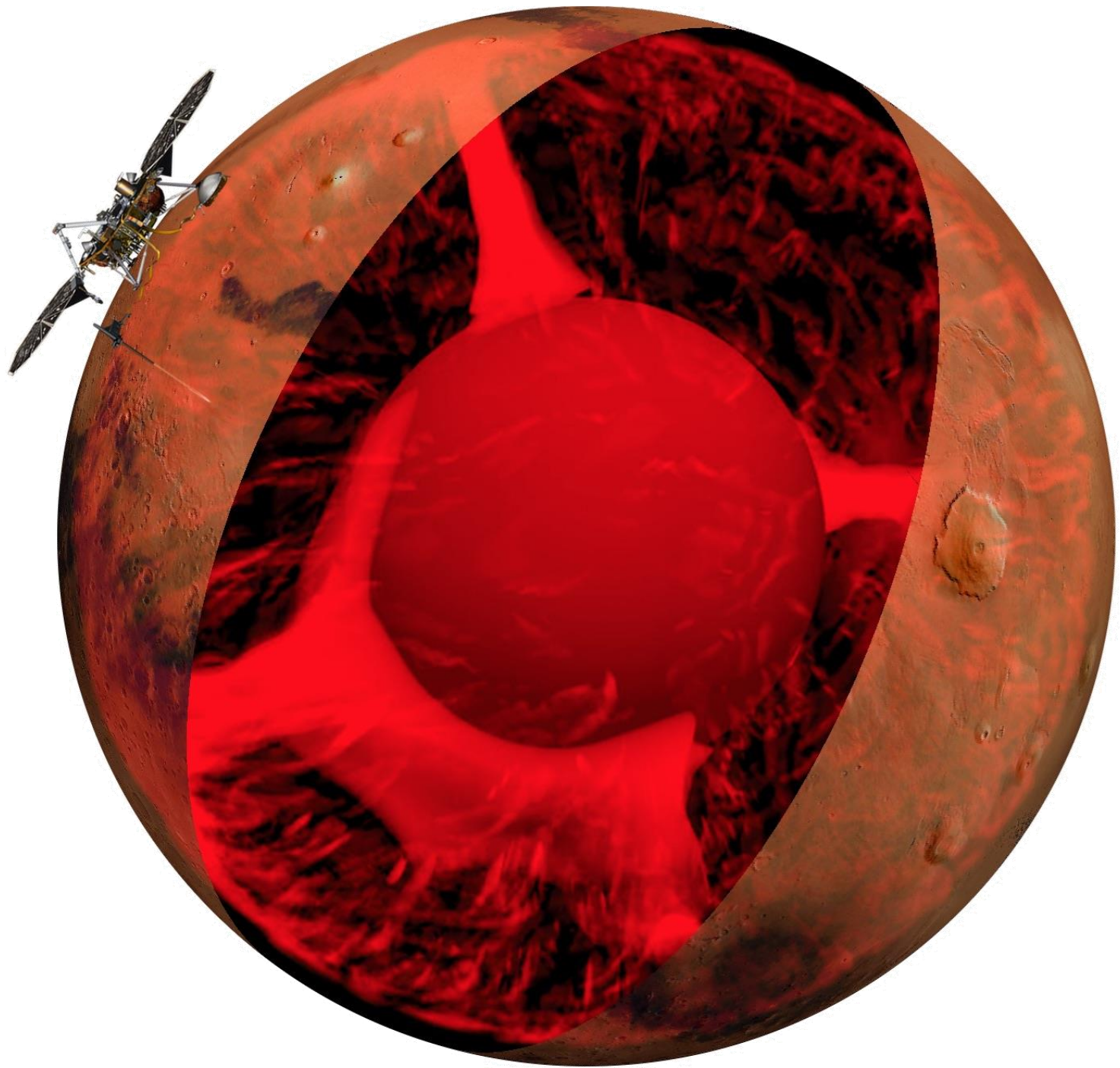
A scale which goes up in even steps.

Logarithmic

A scale where each time you go up one along the scale the number gets ten times bigger.

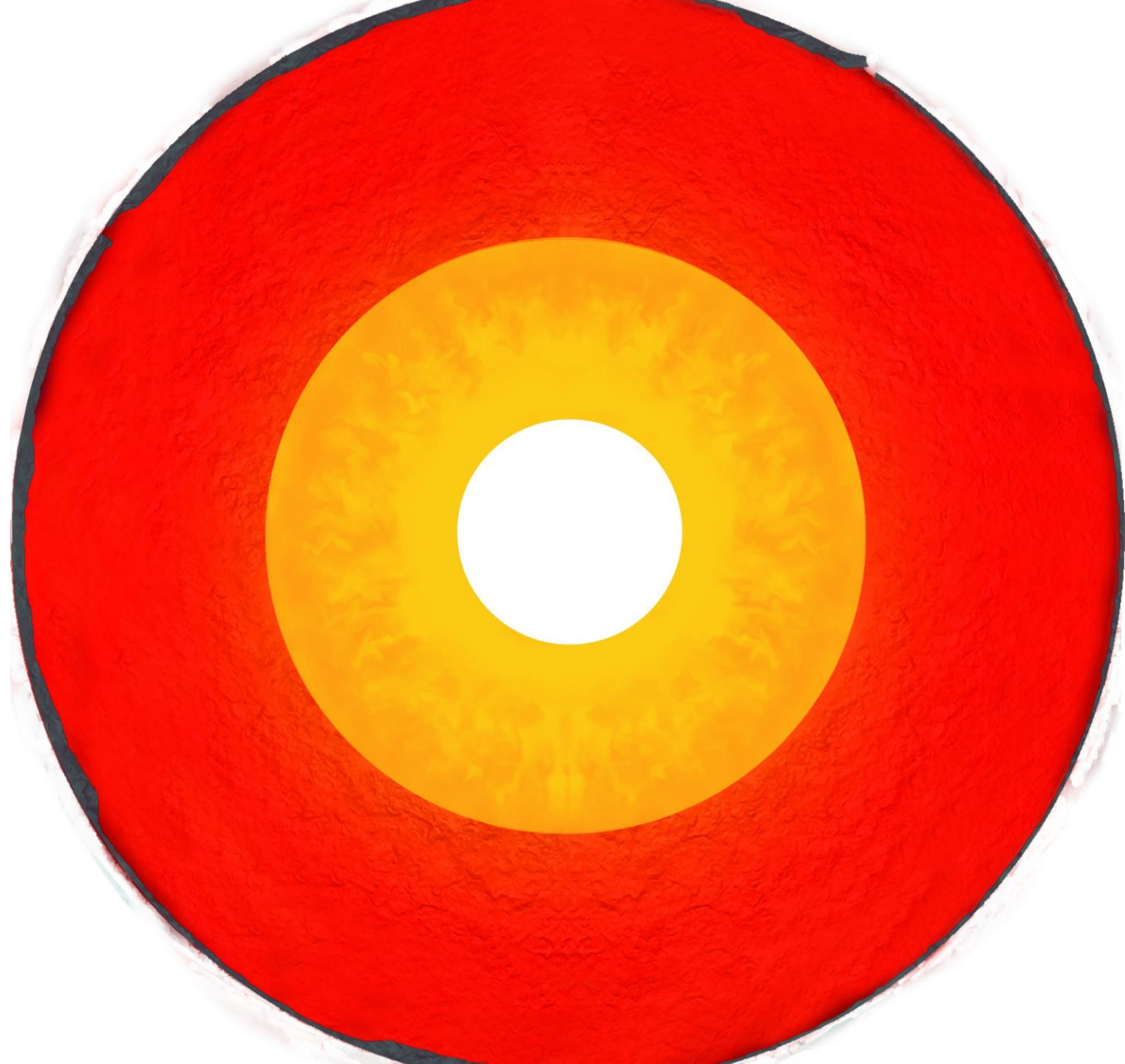






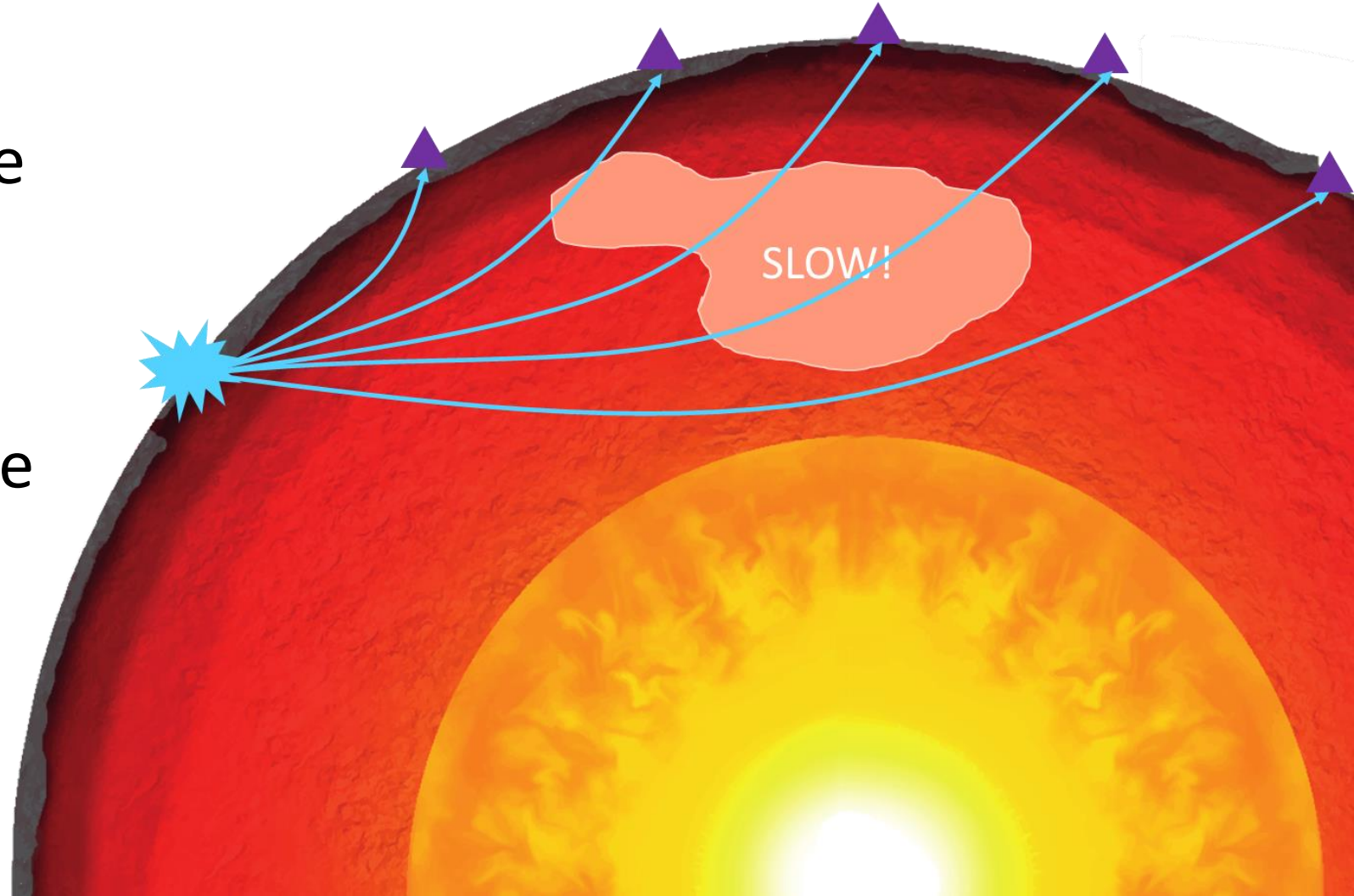
What have we
learned?

The Earth is made of
four basic layers:
**crust, mantle, inner
core, and outer core**



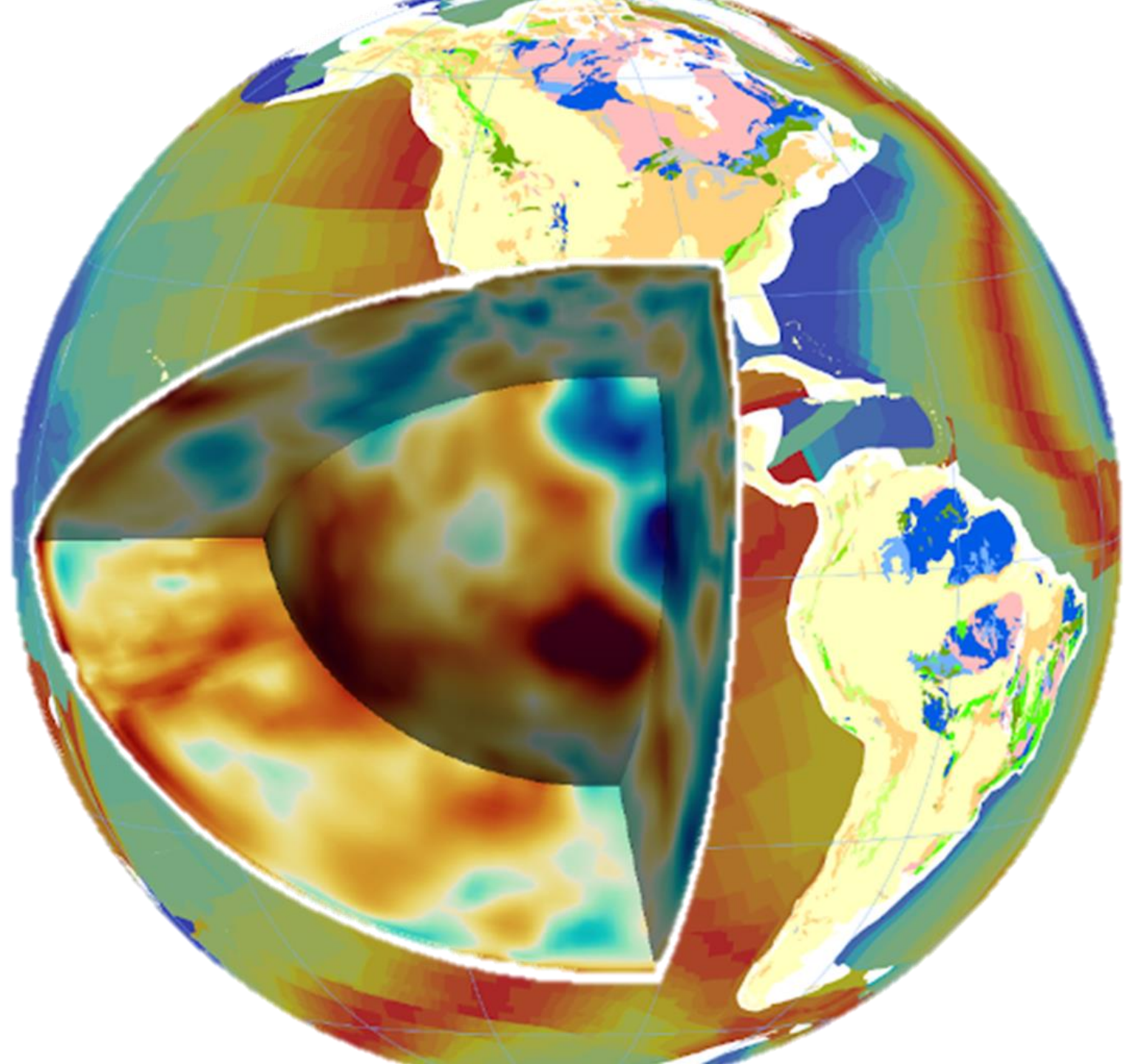
What have we learned?

We can 'look' at structures inside of the Earth using **seismic tomography**. We measure arrivals of **seismic waves** from **Earthquakes** across the world, and use this to make a 3D image of where in the Earth **seismic waves** travel slower and faster



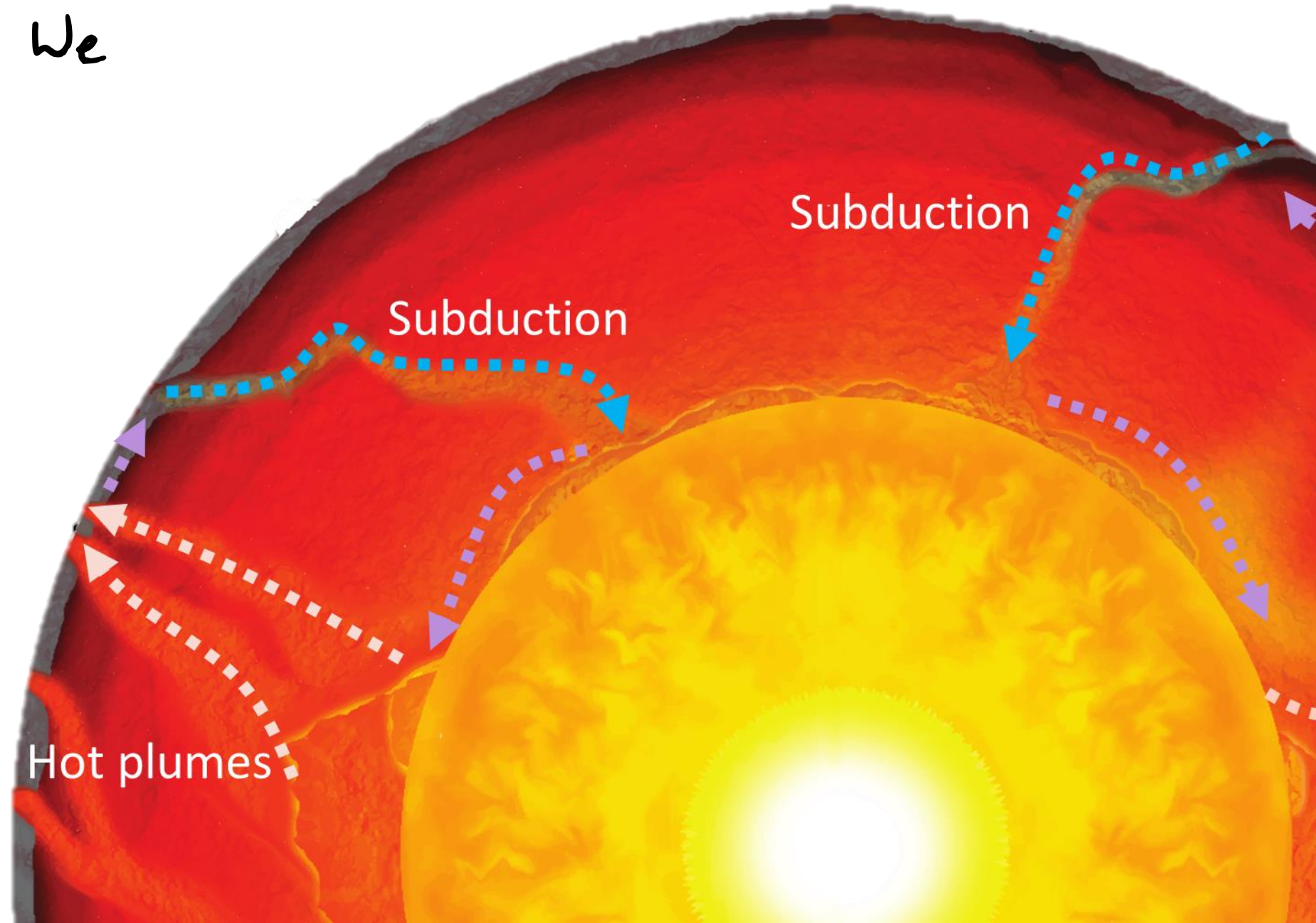
What have we
learned?

Seismic waves move
faster in colder **mantle**
and faster in hotter
mantle, so
tomographic images
can show us hot and
cold patches in the
mantle.



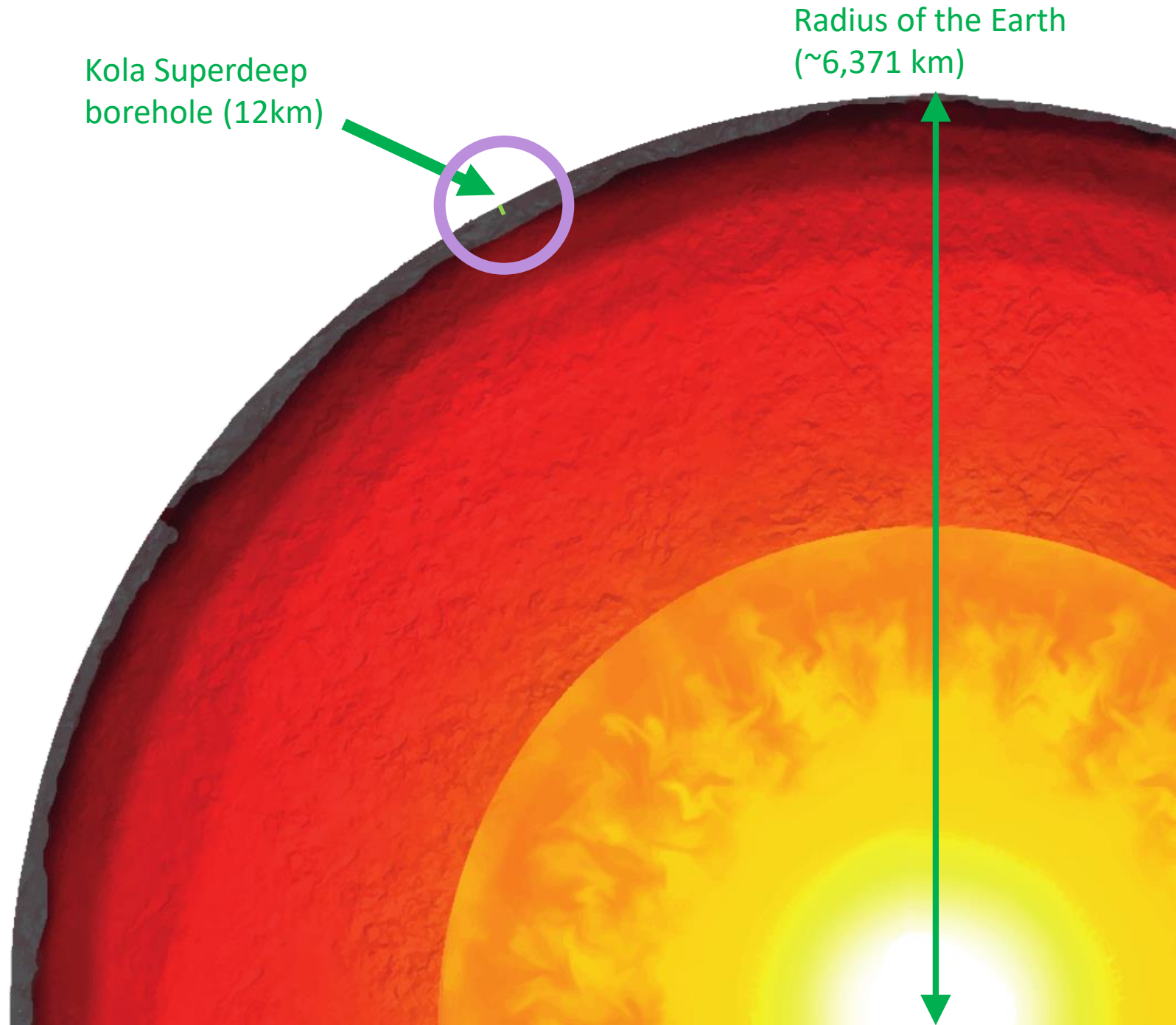
What have we
learned?

The mantle is
convecting.



What have we
learned?

We're still trying to
drill down to the
mantle, in the
meantime we have to
make-do with bits of
mantle from
kimberlite pipes.



What have we
learned?

The **mantle** is solid
(and green)! It is made
from **peridotite**.



What have we
learned?

Creep allows **solids** to flow over a long time. On a short timescale creeping materials look **solid**, but over time they flow in a **fluid** way, like a **liquid**. So the **mantle** can be **solid** and **convect** due to **creep**.



What have we
learned?

The **mantle** flows at
about the same speed
that your fingernails
grow.



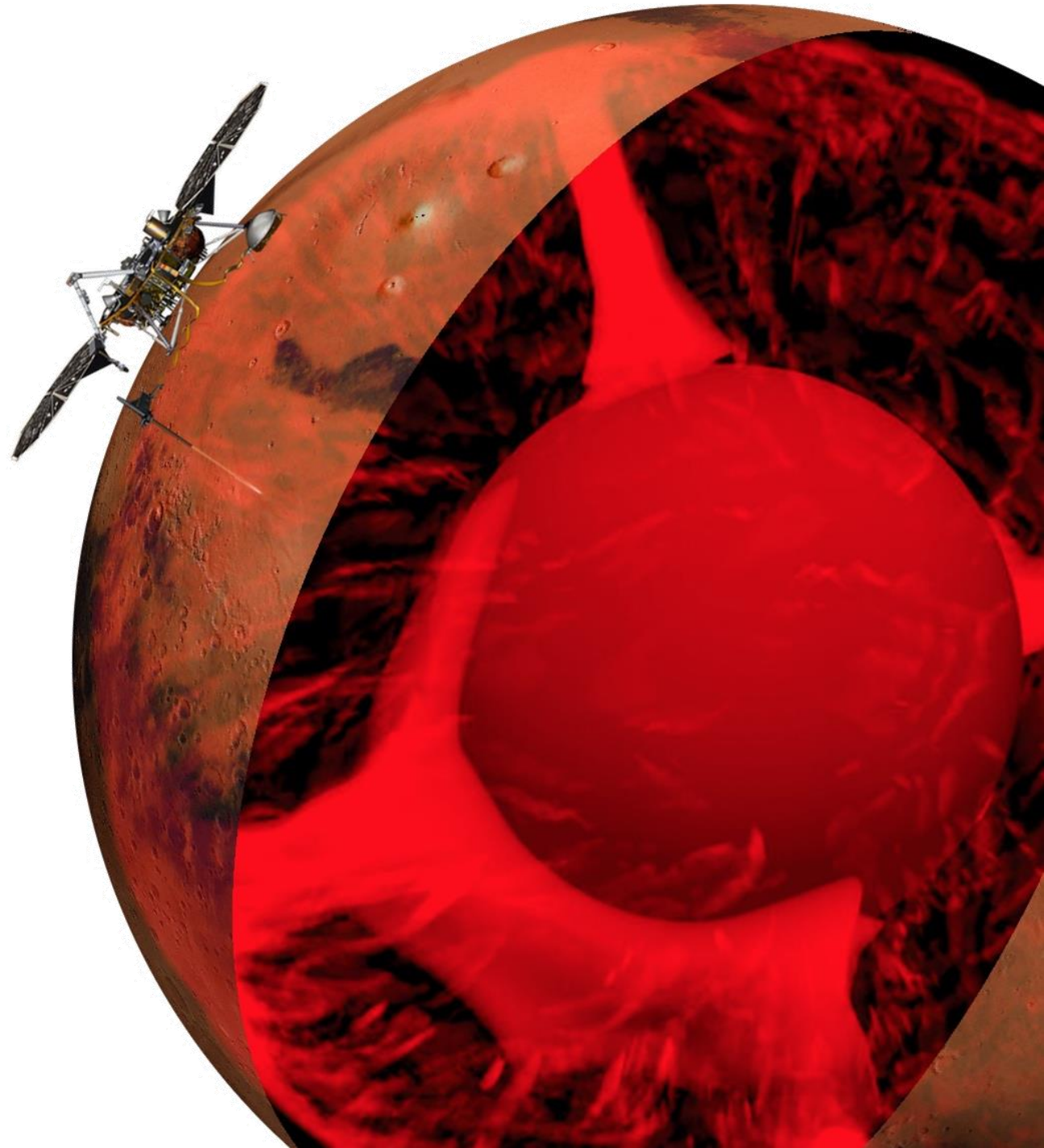
What have we learned?

Ice also flows by **creep**,
and making models of
this allows us to date
ice and get records of
past climate, which can
help us answer
questions about
modern climate change



What have we learned?

Understanding **convection** in the Earth's **mantle** is useful in understanding where volcanoes happen, understanding controls evolution of island species, studying convection in the **outer core** and so Earth's magnetic field, and trying to study the **mantle** of other planets.



What have We learned?

In order to answer questions about the Earth like these, people with lots of different areas of expertise have to work together:
computer, field, and lab **geoscientists**





Video:


[https://vimeo.com/281](https://vimeo.com/281326035)

[326035](https://vimeo.com/281326035)

WHAT IS A
GEOSCIENTIST
LIKE?

WHAT DOES A
GEOSCIENTIST
DO?





ANY QUESTIONS?

About the Earth, geosciences as a subject, or anything else