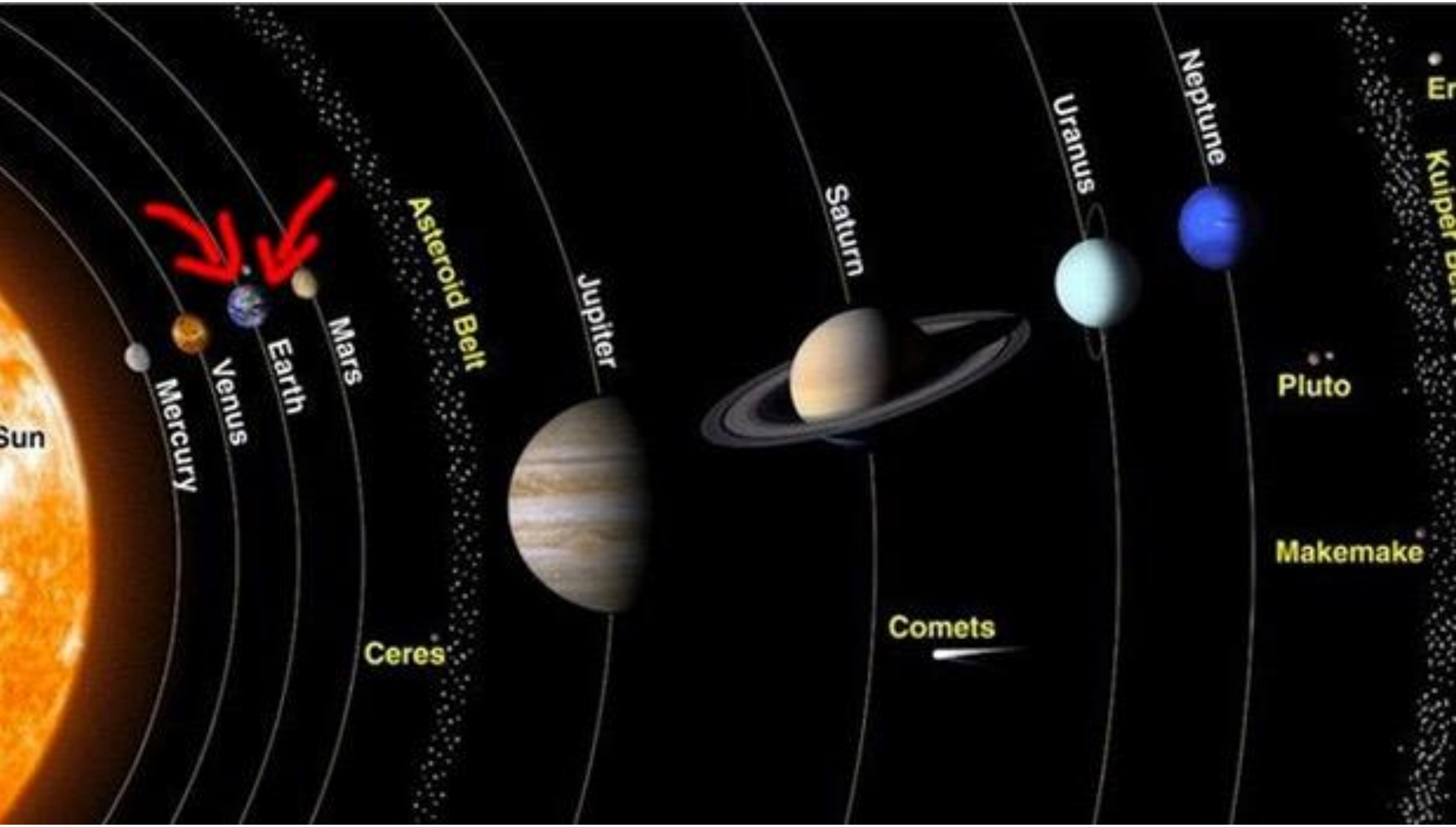
The Earth is a special place. It is the only place in the Universe where we are sure we can survive and thrive and, as far as we know, the only place where life has evolved.



Sun
Mercury
Venus
Earth
Mars
Asteroid Belt
Ceres
Jupiter
Saturn
Comets
Uranus
Neptune
Pluto
Makemake

Talk about Earth

1. Special Planet
   Right environment, Temperature, Atmosphere, water

How it looked before,,,,,means how it evolved as seen today

Not only weather and climate but internal forces-

a. Endogenic forces b. Exogenic forces

Volcanic activity
Earth Quakes
shaping of landscape...

you will be introduced to your home planet. The first part explores very briefly what is unique about the Earth when compared with the Moon and other terrestrial planets: Mercury, Venus and Mars.

The second part investigates the structure of the Earth: how it is divided into core, mantle and crust, and the evidence on which that division is based.

Finally, the lines of evidence concerning the composition of the Earth and its constituent layers are drawn together from various sources, such as meteorites and samples of the mantle.

Many things happening on earth (at different time scale)
Our aim is to –

1. Describe and analyzing the way the solid earth works....

2. Composition of the Earth and its constituent layers

3. Evolution of the Earth from a cloud of gas & dust via ocean of magma to a breathable atmosphere.

So,,,, we try to learn in the first part-

1. Introduction to the Home Planet—Earth
2. Comparison of Earth with moon
3. Structure of the Earth

Planet Earth is UNIQUE-

Most of the aspects are taken for granted-

Characteristics of the Earth-
Water + Oxygen

MARS- water locked in ice caps....
presence of water in the past
CO_2, N_2, atmosphere,,,,

VENUS- Thick atmosphere but CO_2 + SO_2
temperature intolerable

Mercury and Moon- Dry, no atmosphere

Earth Interacting Systems

ATMOSPHERE- Envelope of gases that surrounds the earth

HYDROSPHERE- Water on the planet includes all types – ocean, lake, rivers etc....

GEOSPHERE- solid Earth

BIOSPHERE- all forms of Life

We are interested in GEOSPHERE and how it interacts with atmosphere Hydrosphere and biosphere...

Moon has 2 different surfaces

1. Highland (elevated regions like continents)-
   Pale coloured, dense covering of Impact crater

2. Maria- (Latin for 'sea')- depressions like sea
   Darker flatter region with fewer crater

It has been found that crater are due to impact of meteorites and is proportional to the age of the surface

Means---- highlands are older than maria......

Radiometric dating suggests that highlands are ~4.4 Ga and Maria are ~3.8-4.2 Ga........confirming the above hypthesis..

Also maria is mostly basaltic in composition
Highlands- Anorthosite (rich in plagioclase feldspar~90%;
10% mafic minerals, uncommon rock on earth)

Hence-
Moon experienced intense meteoritic bombardment in its
Early history, later declined during maria formed.

Magma generated by small amounts of partial melting of the mantle is generally of basaltic composition. Under normal conditions, the composition of basaltic magma requires it to crystallize between 50 and 70% plagioclase, with the bulk of the remainder of the magma crystallizing as mafic minerals. However, anorthosites are defined by a high plagioclase content (90–100% plagioclase), and are not found in association with contemporaneous ultramafic rocks. This is now known as 'the anorthosite problem'.

A typical theory is as follows: partial melting of the mantle generates a basaltic magma, which does not immediately ascend into the crust. Instead, the basaltic magma forms a large magma chamber at the base of the crust andfractionates large amounts of mafic minerals, which sink to the bottom of the chamber. The cocrystallizing plagioclase crystals float, and eventually are emplaced into the crust as anorthosite plutons. Most of the sinking mafic minerals form ultramafic cumulates which stay at the base of the crust.

What happened to other planets-

Mercury- appear similar to the moon with a highly cratered ancient surface

Mars- different surfaces of Mars appear similar to those of moon

Hence assuming a similar impact history to the moon, Mars has given ~3.8 Ga age, however, absolute ages are yet to known.

Venus- lower cratering density suggesting a much younger surface age

Impact crater on earth are rarely known as moon suggesting Young surface

Oldest terrestrial rock are almost 3.9 Ga old on earth
Ocean rocks < 200 Ma

The period of time on earth, between its formation at 4.55 Ga
And the age of the earliest rocks at earth is 3.9 Ga,,,is known as "HADEAN"...

HADEAN records are obtained from other planets and Meteorites...

Lack of terrestrial records during HADEAN is due to
Weathering process + erosion

MARS is also having this but atmosphere is very thin and
Ephemeral nature preserves very old record of surface.

VENUS – no hydrosphere...so young surface of Venus needs
Another explanation...

Another concept was coined of heat holding in the core
Earth & Venus---same size....
Venus-....plate tectonic???
No

The structure of the EARTH-
Study of Earthquakes- Seismic waves,,,,seismology
Provide information on the structure of the earth..

Seismic waves-

1. P waves (body wave, compression and dilation, sound waves)
2. S waves (body wave, motion is in perpendicular direction of wave)
3. Love and Rayleigh – confined largely to the surface of the Earth and most destructive..... but they do not provide information about the interior of the Earth...... Hence not considered here.

The speed of a seismic wave is related to the physical properties of the medium through which the wave travels. In general, the wave speed is a function of two properties – the **elastic modulus** and the density – and is of the form:

$$\text{speed} = \left(\frac{\text{elastic modulus}}{\text{density}}\right)^{\frac{1}{2}} \tag{1.1}$$

For example- in air- speed of sound is 330 m/second
In steel- 6000 m/second
Young modulus- 9.2 x 10^10, density = 8.1 x 10^3 kg/m3

Elastic modulus is a measure of strain occurs in a material
When subjected to a given amount of stress, and is defined
as the ratio of stress to strain
BULK modulus relates to compressibility of a medium
SHEAR modulus relates how rigid the medium is

The equation for the speed of P-waves, υ_P, is:

$$\upsilon_P = \left(\frac{K + \frac{4\mu}{3}}{\rho} \right)^{\frac{1}{2}} \tag{1.2}$$

where K is the bulk modulus, μ is the shear modulus and ρ is the density. The equation for the speed of S-waves, υ_S, is:

$$\upsilon_S = \left(\frac{\mu}{\rho} \right)^{\frac{1}{2}} \tag{1.3}$$

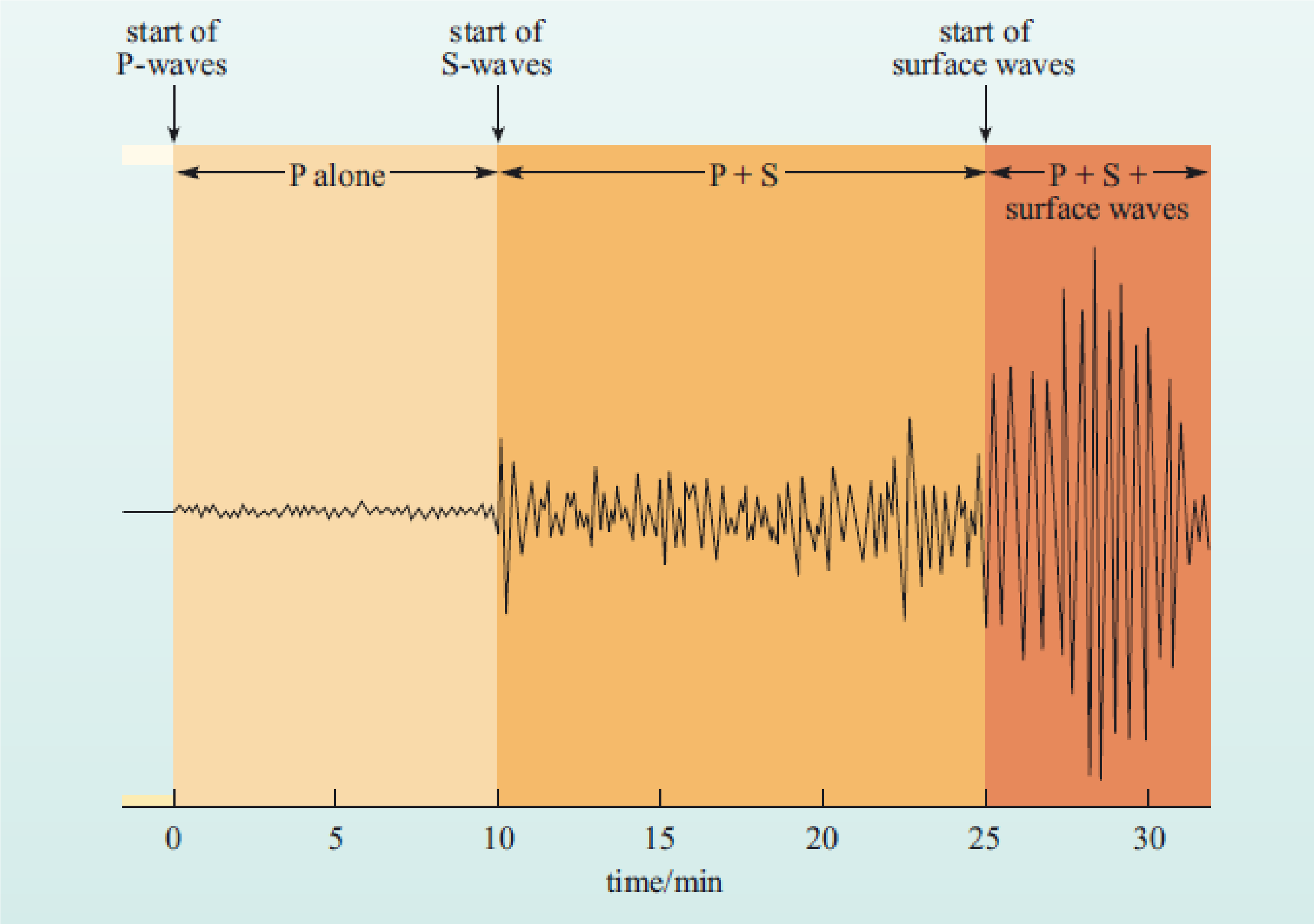
■ Can you see why υ_P is greater than υ_S?

- Given that both K and μ are positive numbers, $K + \frac{4\mu}{3}$ is always greater than μ, so v_P will be greater than v_S.

- What do Equations 1.2 and 1.3 infer about P- and S-wave speeds in liquids of similar densities to solids?

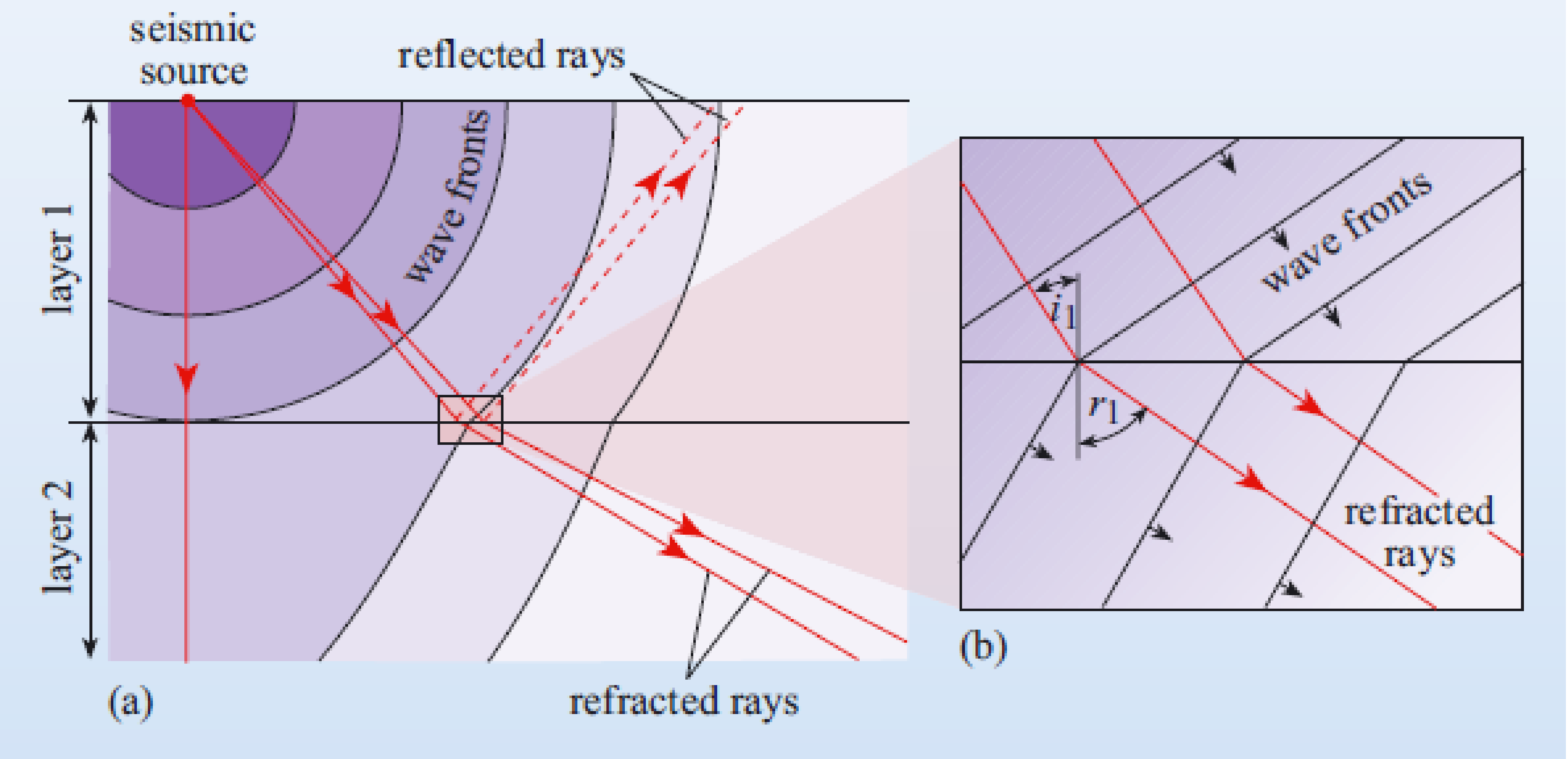
Given that a liquid has no rigidity (it occupies the shape of any containing vessel), it cannot be deformed. Hence μ must be zero. Therefore, liquids cannot transmit S-waves. Also, for a given density, the P-wave velocity is lower in a liquid than in a solid.

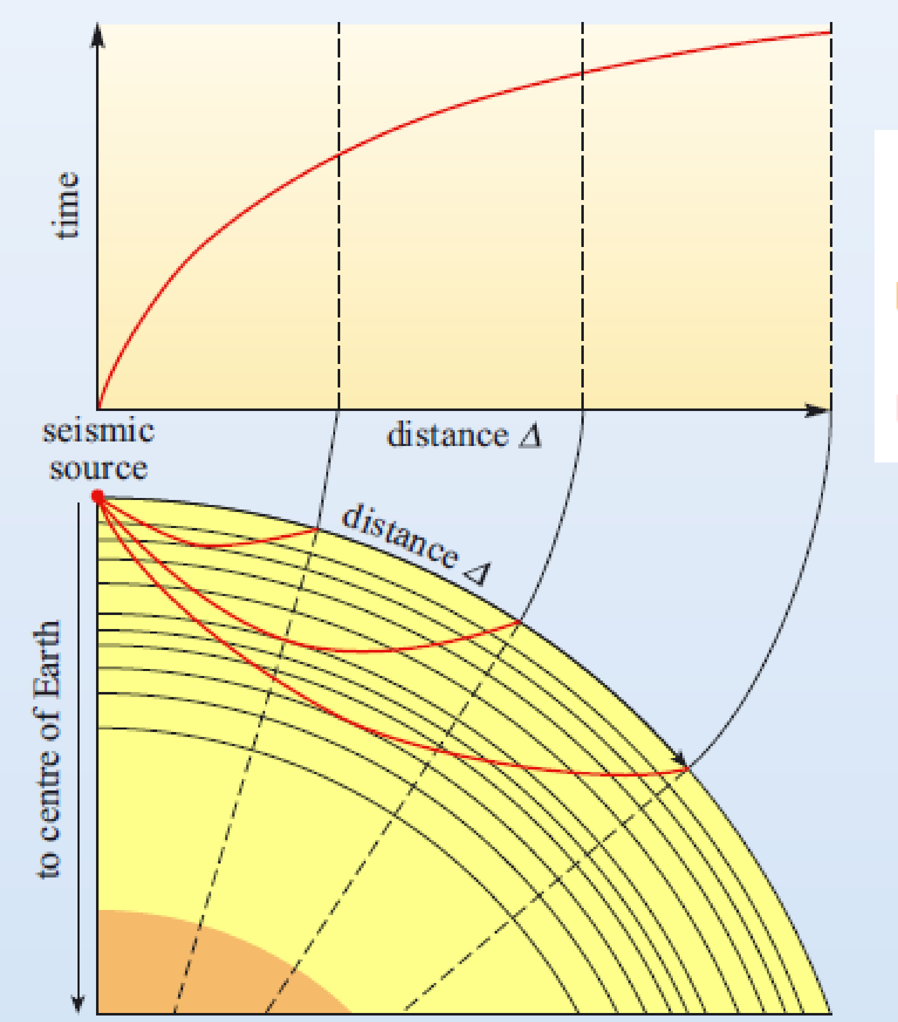
Difference in the arrival time of P and S waves can be calculated To compute the distance of earthquake from the seismogram, an instrument to measure the earth quake waves.



Seismic refraction

$$\frac{\sin i}{\sin r} = \frac{v_1}{v_2}$$

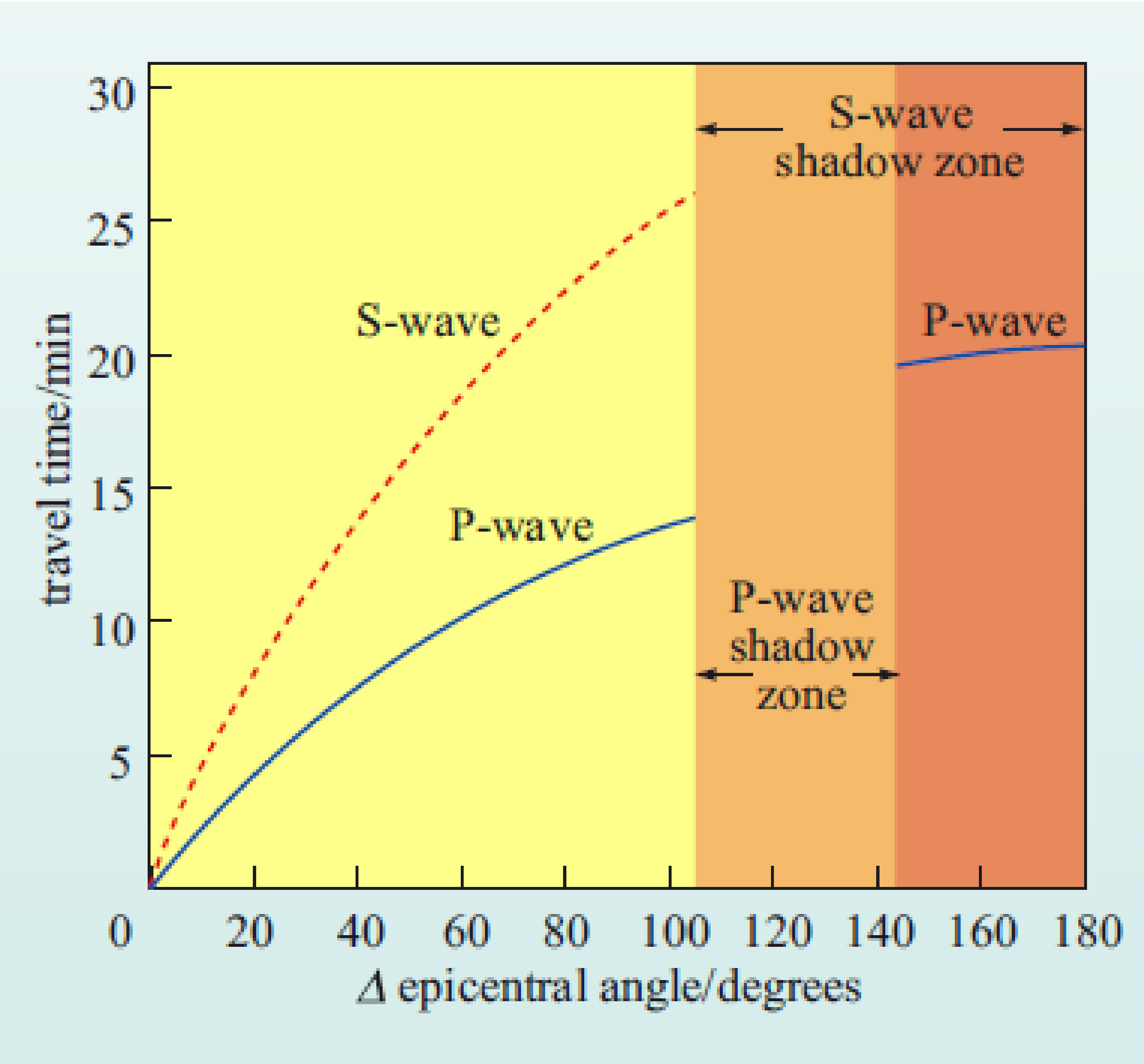




$\frac{v_1}{v_2} = \sin i$, i.e. $\sin r = 1$, meaning that $r = 90°$.

- What do you think happens to the wave path when it strikes a boundary at the critical angle?
- It is reflected rather than refracted.

- Imagine the Earth consists of a series of thin concentric shells each with a seismic velocity slightly greater than the one above. What will be the shape of the ray path?
- The ray path will be refracted to a shallower angle at each boundary and curve back towards the surface.

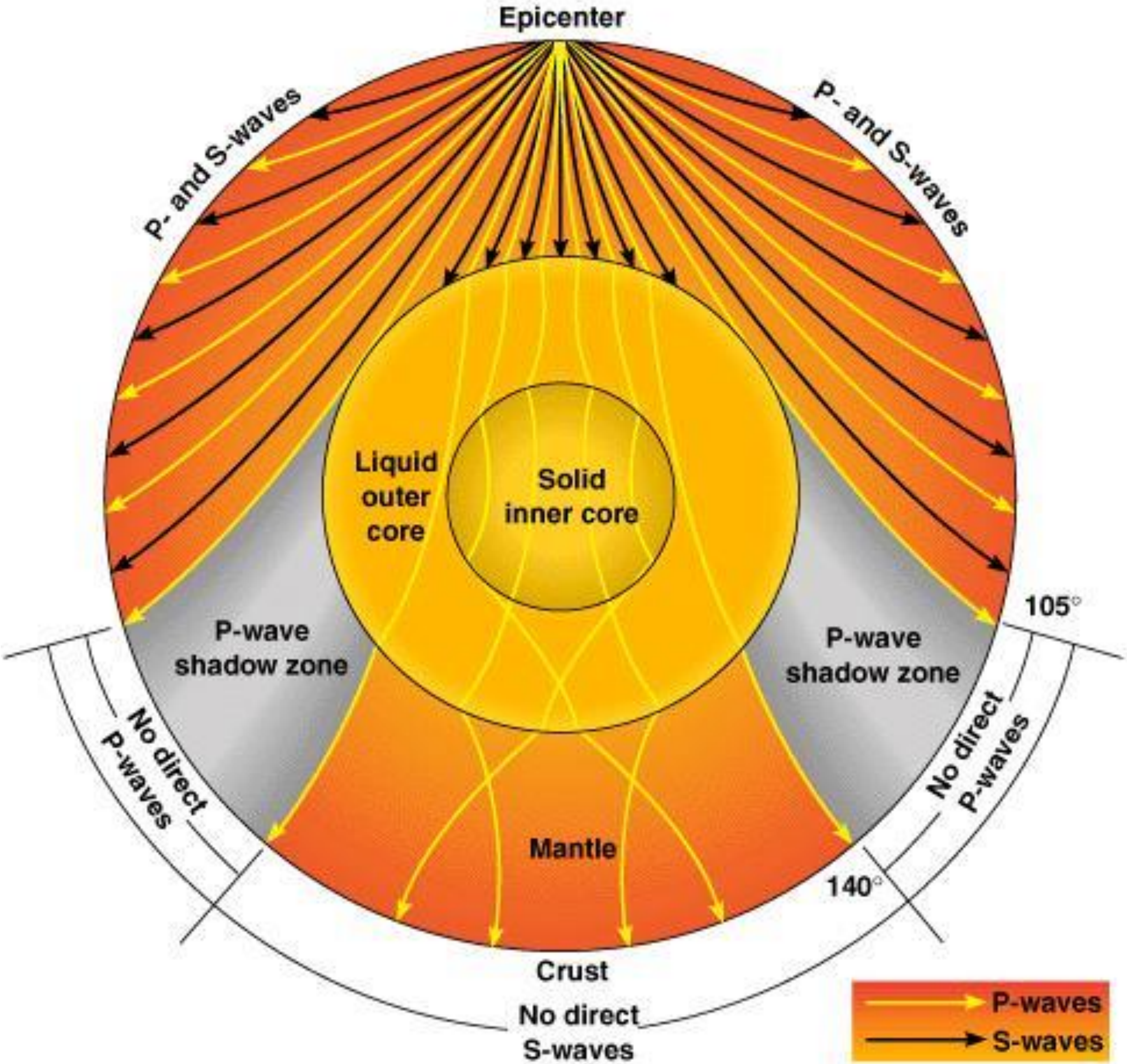


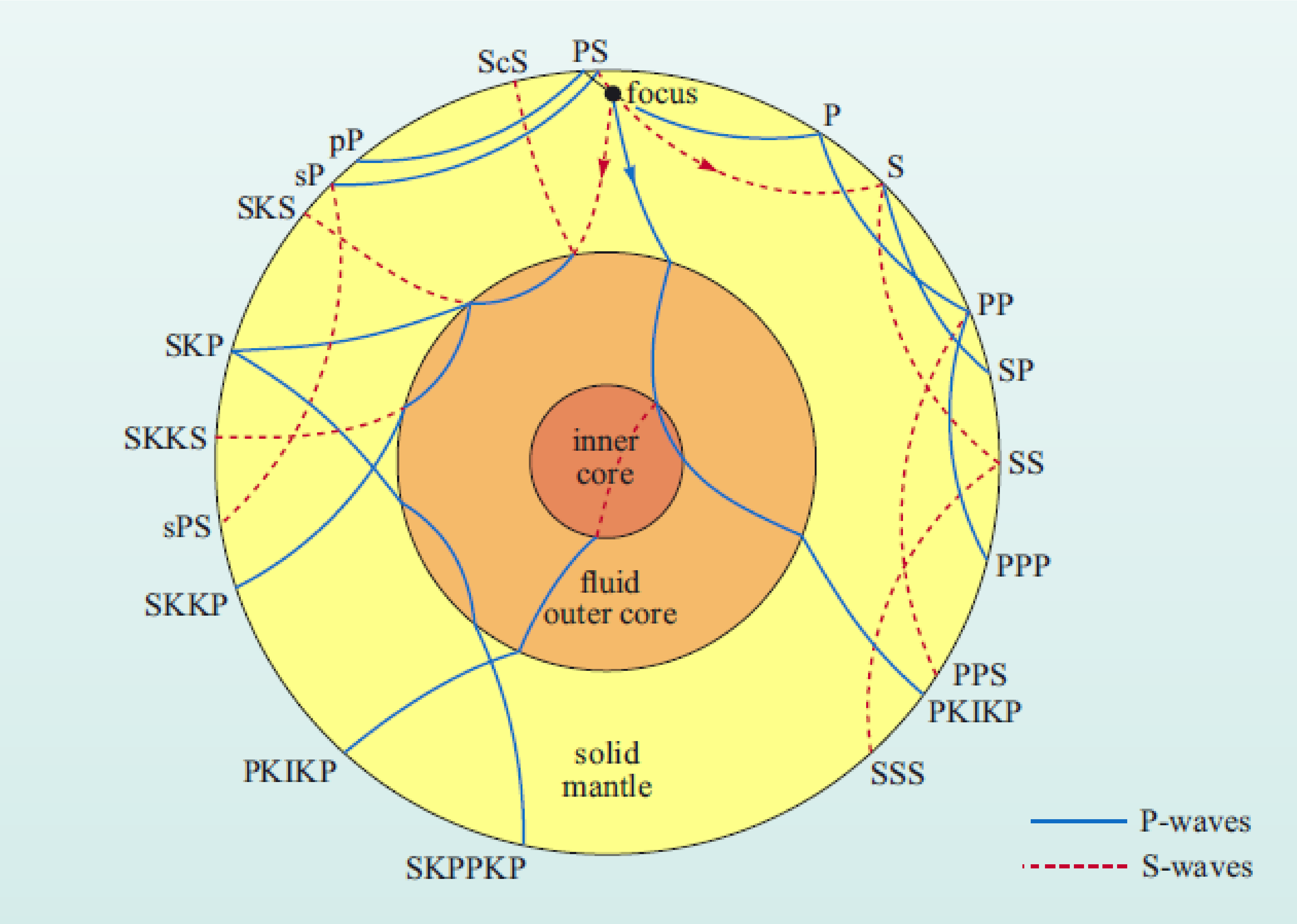
The distance of seismic receiver from a seismic source can be Measured in km but is usually expressed in terms of angle subtended At the centre of the Earth.

A plot of arrival times for different seismic Waves against delta (the epicentral angle) known as travel time curve

Arrival time of P wave disappear after the extended angle
Of 105o but it again re appear after 142o,,,,,however, S waves
Do not appear again after 105o.

The areas of the Earth's surface at these epicentral angles where there are no seismic waves are known as **shadow zones** and they are more or less the same for any earthquake, no matter where on the Earth it originates. This simple observation shows that the internal structure of the Earth must be radially symmetric.


Epicenter
P- and S-waves
P- and S-waves
Liquid outer core
Solid inner core
P-wave shadow zone
P-wave shadow zone
105°
No direct P-waves
No direct P-waves
140°
Mantle
Crust
No direct S-waves
P-waves
S-waves


PS
ScS
focus
P
pP
sP
SKS
S
PP
SKP
SP
SKKS
inner core
SS
sPS
fluid outer core
PPP
SKKP
PPS
PKIKP
PKIKP
solid mantle
SSS
SKPPKP
P-waves
S-waves

all the seismologist has to go on are the arrival times of P- and S- waves and a reasonable knowledge of the seismic velocities of various rock types as they occur at the Earth's surface. The process of converting these data into information on the internal structure of the Earth is complex and was originally achieved using a laborious mathematical procedure known as **inversion**. (The