Lecture Notes – Week 3

STRUCTURE OF THE EARTH: SEISMOLOGY

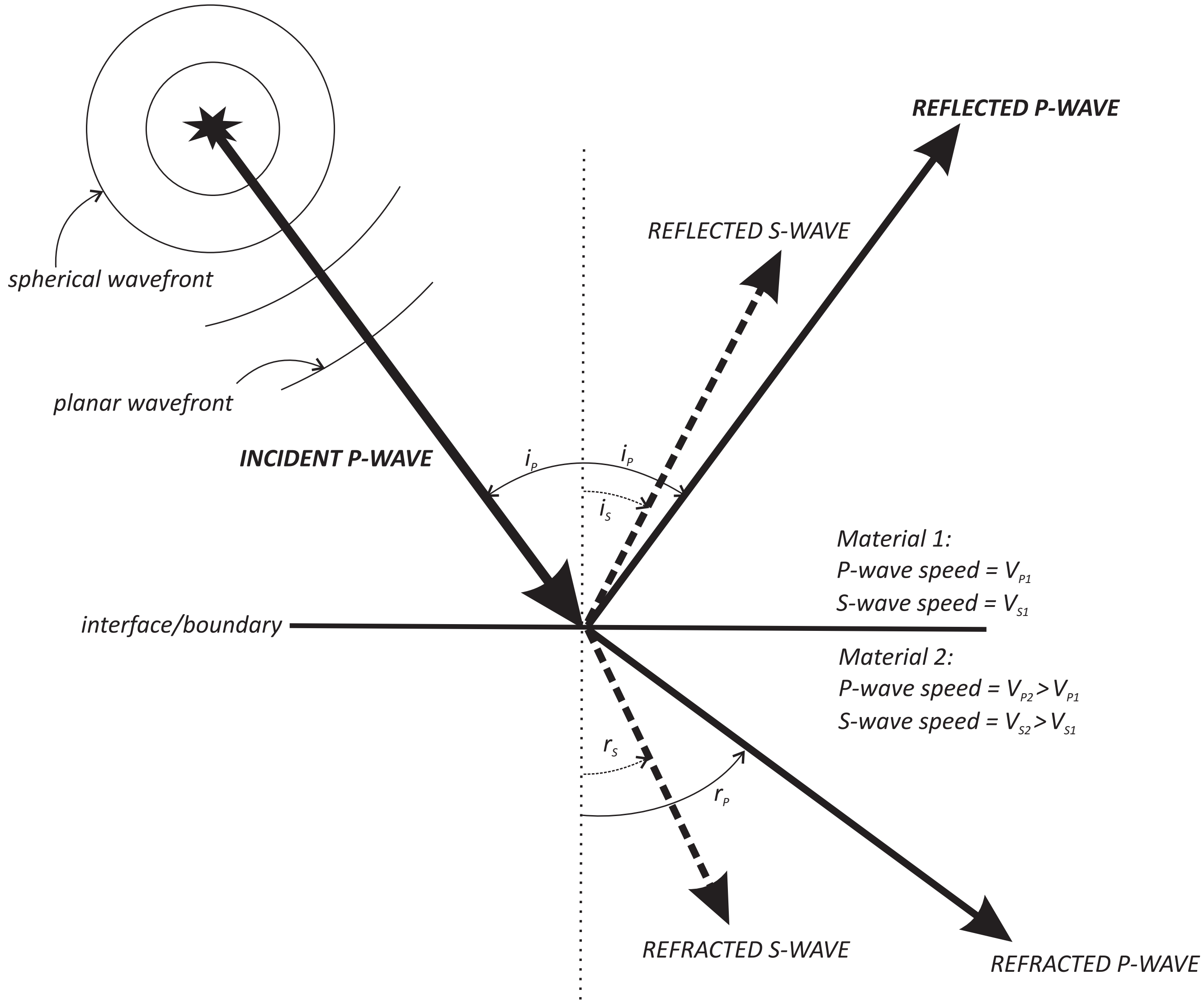
STRESS WAVE REFLECTION AND REFRACTION

Reading: Fowler, Chapter 4.3 & 4.4

Objectives:

- Continue discussion of stress waves, focusing on how they travel through the earth, and how they interact with boundaries between layers in the earth

The diagrams on the following pages highlight the important concepts for this week. All the details can be found in the assigned reading.



The dynamic stress traveling from a far-away source arrives at the boundary or interface between two distinct (but mechanically connected) materials with a planar wavefront; consider the 'ray path' (bold arrow) of the incident P-wavefront when it hits the boundary.

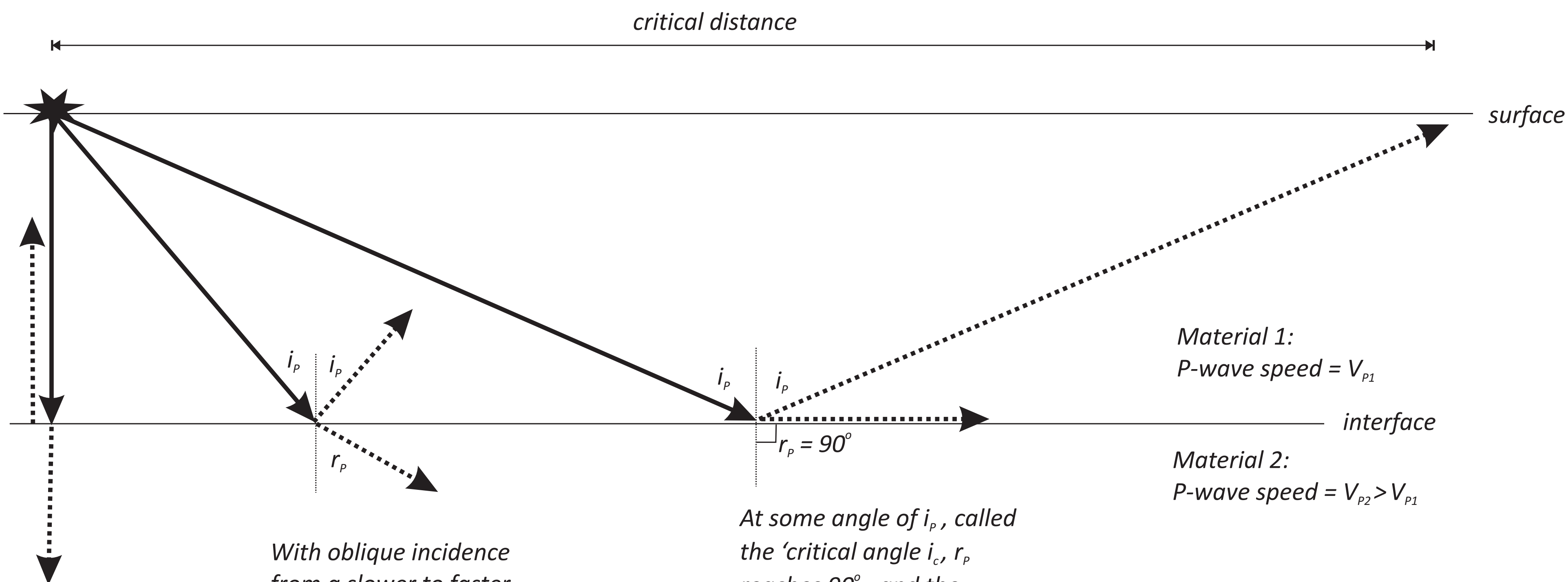
At the boundary or interface, the incident P-wave is partitioned into four new waves: a *reflected* P-wave and S-wave, and a *refracted* P-wave and S-wave.

The reflection and refraction angles (measured from an arbitrary plane normal to the surface) obey Snell's Law:

$$\frac{\sin i_P}{V_{P1}} = \frac{\sin i_S}{V_{S1}} = \frac{\sin r_P}{V_{P2}} = \frac{\sin r_S}{V_{S2}}$$

the magnitudes of each new wave depends on the wave speed differences

Focus on the P-waves only, but same applies to S-waves as well:



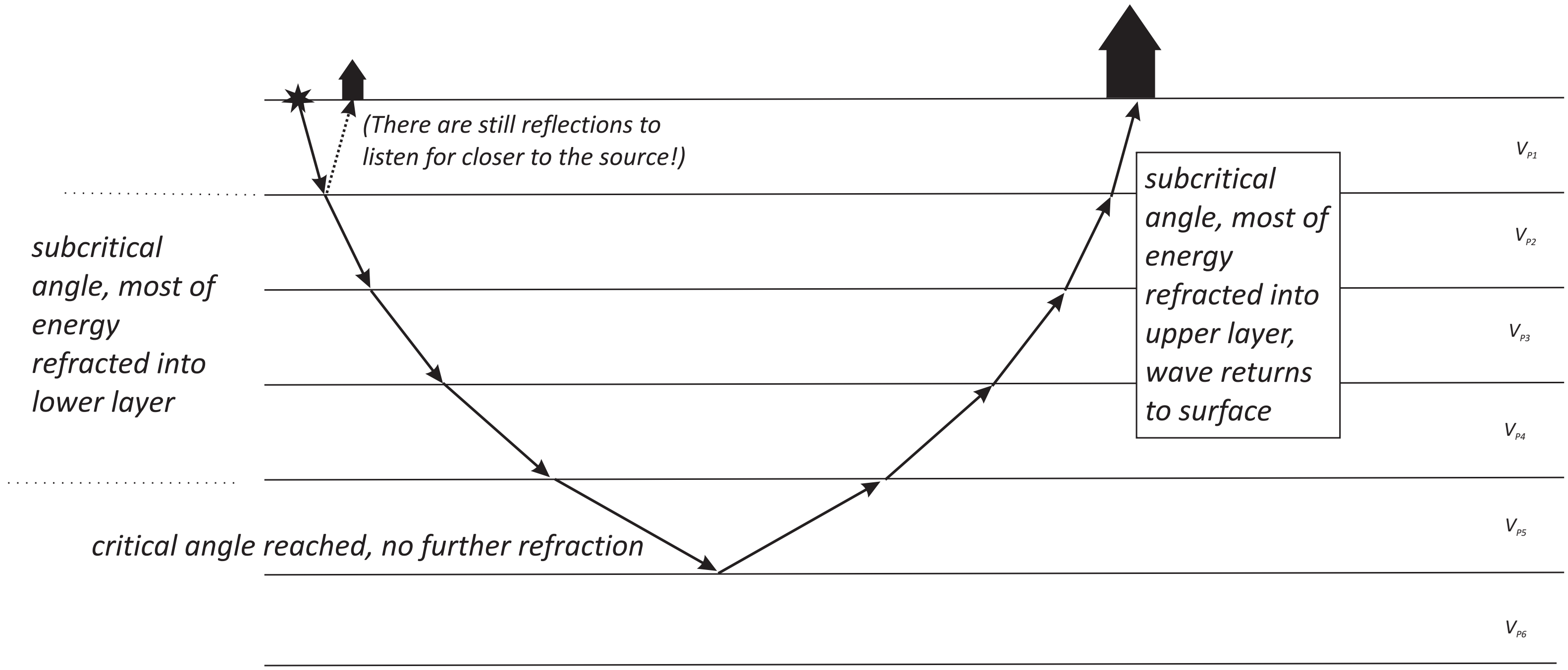
Normal incidence: wave is partially reflected, partially transmitted with no refraction - since $i_P = 0$, therefore $r_P = 0$ (Snell's Law)

With oblique incidence from a slower to faster material, as i_P increases, so does r_P - as per Snell's Law, the relationship is not linear so r_P approaches 90^o before i_P does.
The refracted wave carries much of the original energy

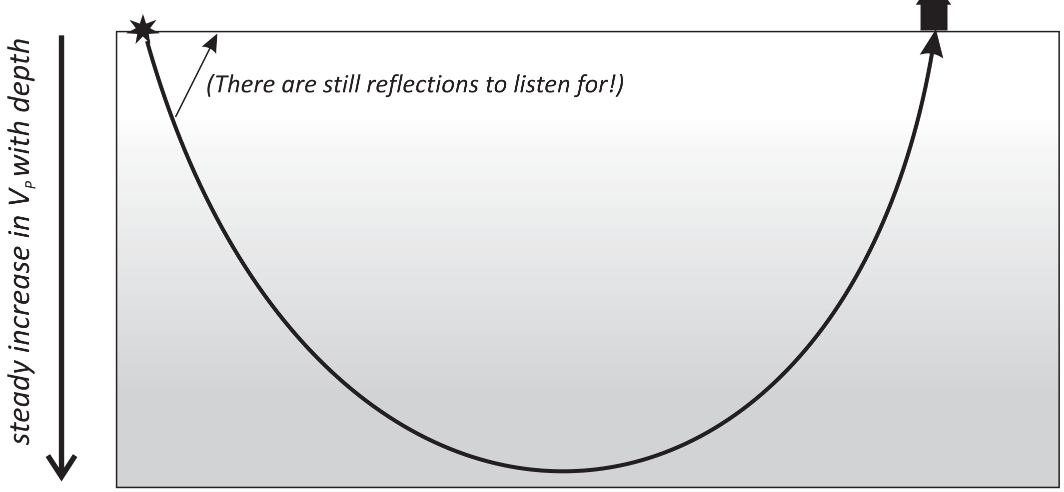
At some angle of i_P, called the 'critical angle i_c, r_P reaches 90^o, and the refracted wave travels along the boundary. From Snell's Law: $\sin i_c = V_{P1}/V_{P2}$

Most of the original energy is reflected, leading to a notable increase in the amplitude of the reflected wave measured at the surface, at the 'critical distance' from the source.

*Consider an example with P-wave **refraction** through many layers, increasing wave speed with depth:*



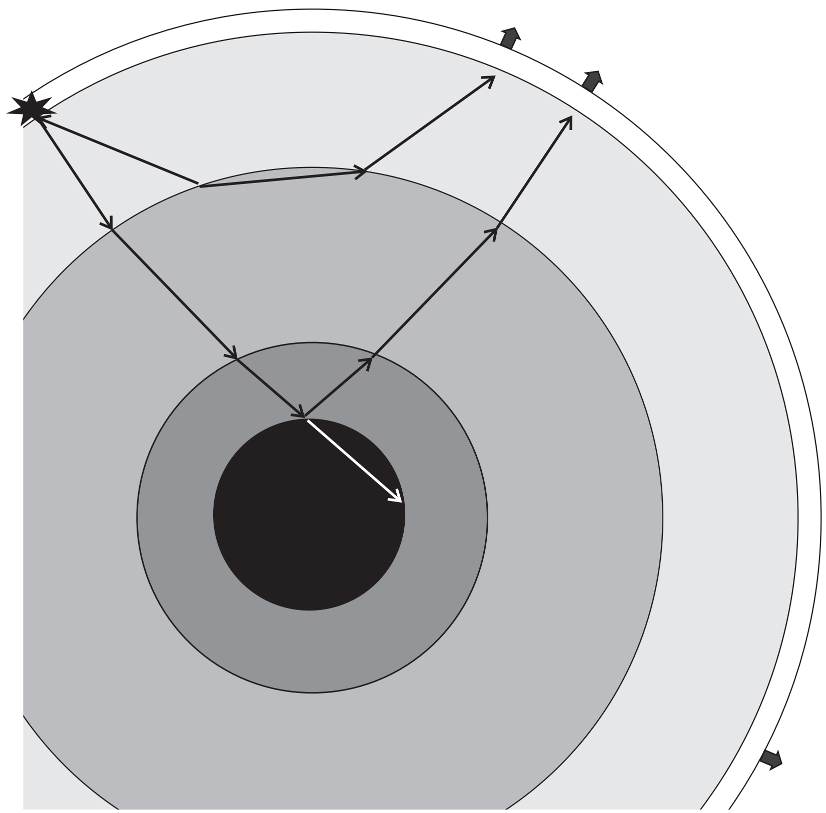
Consider and example with wave speed increasing with depth (not layered):



The wave refracts as if encountering many thin layers, and will eventually reach a critical angle and be reflected back toward the surface

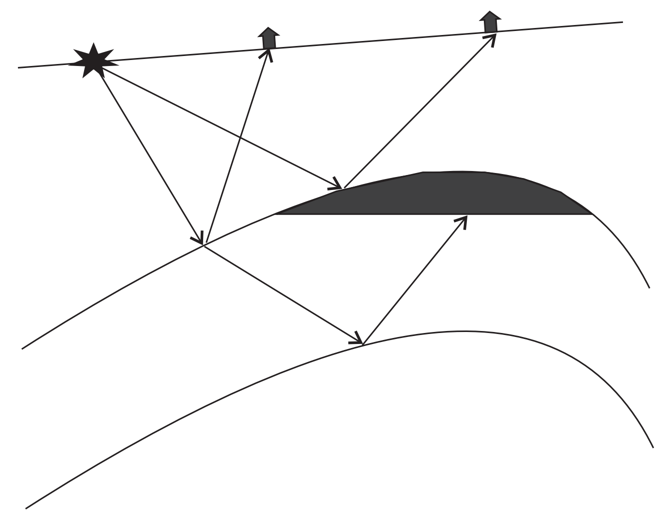
Only a few examples of the possible waves and paths are shown in the examples below - consider the other possibilities!

Large Scale structures and layers for investigating the entire earth



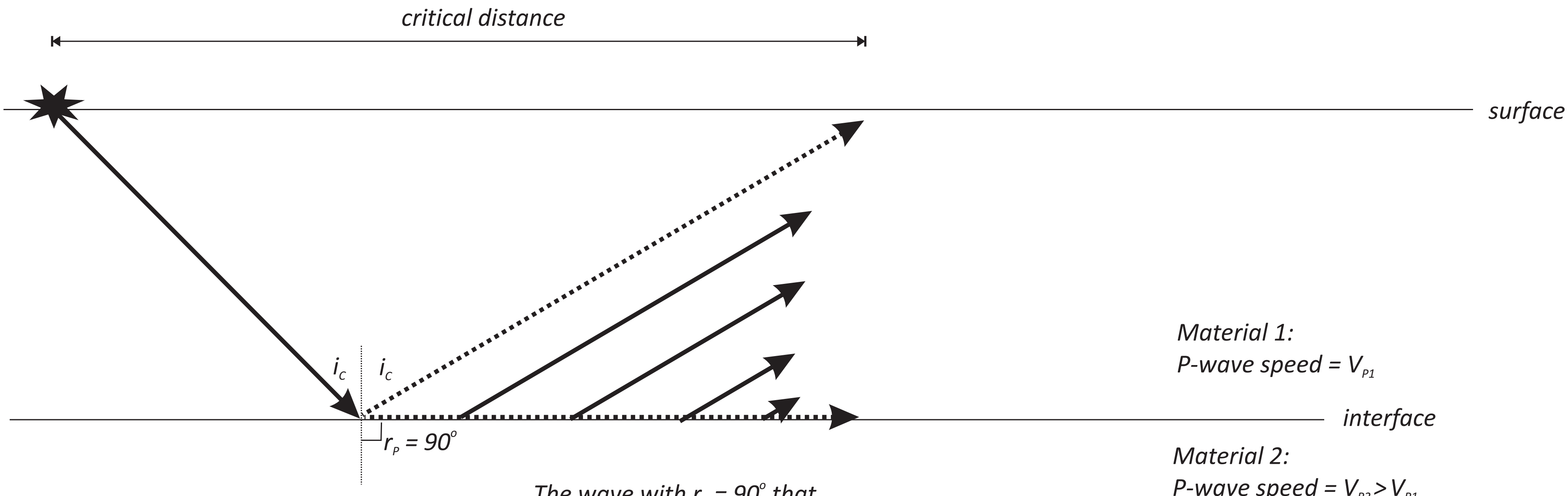
Smal and medium l scale structures and layers for resource exploration, investigating the crust and upper mantle

OR



Seismological surveys are based on knowledge of how stress waves travel through different layers from a source of energy to the location of a seismometer. The geophysicist must solve for the unknown of interest (such as the depth to a layer, the properties of a layer, the source of the energy or earthquake).

One more source of waves to consider: ‘Head Waves’



The wave with $r_P = 90^o$ that travels along the interface at V_{P2} generates new ‘reflected’ waves in the upper layer at reflection angle i_C. These waves will arrive after the main reflected waves close to the critical distance, but since the head wave travels at V_{P2}, they will eventually get ahead and arrive first at a station some location beyond the critical distance