TEACHER NOTES – ASTRONOMY IN THE NEWS #14

THE INTERIOR OF MARS

Slide 2 – Background Science: Structure of Earth

The inner structure of the Earth, or any planet, dictates the future evolution that that planet goes through. The Earth has a mantle that convects. This is where the heat from the core is transferred to the surface through fluid-like motions in the rocks in the mantle. These temperatures cool as they get towards the surface. It is this convective motion that causes the tectonic plates to move, therefore causing the earthquakes and volcanoes that we experience on the surface.

The Outer core, and it's liquid state, is the cause of the magnetic field we have on Earth, or namely the dynamo within the Outer core. For a dynamo we need three conditions to be met:

- A fluid which conducts electricity.
- An energy source which can produce convective motions.
- Kinetic energy

Condition one is met as the Outer core is made of liquid iron, which is conductive. The section condition is satisfied as the Inner core produces heat, which causes convective motions of the liquid iron and nickel Outer core. This heat is produced by a few processes, including the radioactive decay of materials in the core. The final condition is fulfilled by Earth's rotation. The combination of these three criteria causes the magnetic field. Coriolis forces produce, in the liquid Outer core, "rolls" or coils, which as they conduct electricity, induce magnetic fields. The importance of the magnetic field is that it protects the atmosphere from the harsh Solar winds. These winds are made of charged particles which exert a pressure which could strip away the atmosphere over time. The pressure caused by the magnetic field doesn't allow this to happen. This would have been integral in the early atmosphere and allowing the conditions for life to flourish.

IMAGES:

1. (Left) Internal structure of Earth showing the three major layers underneath the Earth's crust: the mantle, the inner and outer cores. The layers also indicate what are the major constituents of each segment.
2. (Top right) Cartoon indication of a role the magnetic field of Earth plays. It protects the atmosphere from the stellar winds of the Sun, and any Solar winds that do manage to get into the magnetic field, they are filtered into the poles to give the Northern and Southern lights, or the aurora borealis and aurora australis.
3. (Bottom right) A rough outline of the tectonic plates and their locations. This is referred to later since Mars doesn't have any, just a solid crust.

Slide 3: Interior of Mars

Mars has some differences to Earth, beyond the obvious ones that we know such as the differing radius and mass, the length of year and the atmosphere. Structurally, the surface of Mars is not broken up into lots of tectonic plates, like Earth is. It appears to have two large tectonic plates that cover the entire planet. This formation of few tectonics tells us that when Mars was formed as a mass of molten rock, it cooled to form a static crust around a rocky mantle.

However, to obtain information about the interior, seismic data is required. Seismic data from Earth and the Moon have allowed scientists to determine the internal makeup of those bodies, and more specifically, the size and the existence of a core within those two bodies, respectively. To obtain this data, the NASA mission InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) landed a seismometer with the goal of the makeup of Mars by making a 3D model of the interior, and a further instrument to measure the internal heat flow. By determining these two things, we can determine the early geological activity of the planet and thus further constrain models for formation of the terrestrial planets.

The seismometer measured 6 seismic events (marsquakes) which fulfilled the criteria of occurring between 27 and 38.5 degrees around the surface as well as strong enough to detect. The instrument detected two types of waves, S waves and P waves, the two major type of waves produced during a seismic event. The most useful waves to determine the nature of the core are the S waves, especially if it is in the liquid state. P waves propagate through both solids and liquids, whereas S waves only travel through solids. Therefore, if the core is a liquid, S waves would reflect from the boundary between the mantle and the core. The depth at which this occurs can be measured using the time taken for the waves to reach the seismometer, and therefore knowing the size of the planet can give the size of the core. There is currently no evidence for a solid inner core on Mars.

The article that this resource is built on can be found here:

https://www.bbc.co.uk/news/science-environment-57935742

IMAGES:

1. (Left) A depiction of the propagation of the marsquake waves throughout the planet. The red lines are the S waves, whilst the blue lines are the P waves. The most important lines are those indicated by bold red, which are those reflected from the liquid core.
2. (Right) The two tectonic plates on Mars. The yellow line shows the boundary between the two, whilst the red dotted line shows the Tharsis plateau where multiple volcanoes are found. The line of three rises are the volcanoes most associated with region and are shield volcanoes, such as those on Hawaii (Mauna Kea) or Iceland. The tallest volcano on Mars, Olympus Mons, is the large rise to the North West within the plateau.

Slide 4 – Activity: How fast are reflected S waves?

This activity is to calculate how fast reflected S waves propagate through the mantle of Mars. The core radius, as well as some key assumptions, are given on the slide. The table on the slide gives two times for each of the 6 marsquakes.

The first time is the time for the S waves to directly reach the seismometer, whereas the second time is the time taken for the reflected waves to be detected. Therefore, taking into account the assumptions, the first step is to calculate how long the reflected S waves took to reach the seismometer from the core. This is calculated by subtracting time 1 from time 2. The velocity is then calculated by using the standard velocity = distance / time. The distance travelled is the difference between the planet radius and the core radius, which is 1,560 km. The velocities for each marsquake are shown below:

Marsquake	Reflected Travel Time (seconds)	Reflected S wave velocity (km/s)
1	344	4.53
2	342	4.56
3	341	4.57
4	339	4.60
5	333	4.68
6	270	5.78

The average velocity of the reflected S waves is thus: 4.79 km/s.

GCSE Specifications:

Specification	Knowledge Point
Pearson Edexcel Astronomy	1.3
Pearson Edexcel Physics	2.6, 12.5, 12.6
Pearson Edexcel Combined Science	P2.6, P12.5, P12.6
OCR Physics B	3.5.3, 4.2.1
OCR Combined Science	P3.5.3, P4.2.1
AQA Physics	4.5.6.1.2, 4.7.1.2
AQA Combined: Trilogy	6.5.6.1.2, 6.7.1.2