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Earthquakes KS3-KS4 presentation – Teacher's Notes

Key concepts:

- To understand what earthquakes are and why they happen
- To understand why earthquakes predominantly occur at plate boundaries
- To understand that earthquakes release seismic waves which can be measured using seismometers
- To understand the difference between the Moment Magnitude Scale and the Modified Mercalli Scale
- To understand some of the ways buildings can be made more earthquake proof
- To be able to recall some earthquake case studies

Slide 2-3: What is an earthquake?
Watch National Geographic montage of earthquakes:
https://video.nationalgeographic.com/video/earthquake-montage

- Earthquakes are vibrations caused by the movements of the Earth's plates
- They occur when stresses built up in the plates are suddenly released
- Earthquakes are natural hazards – extreme natural events that cause loss of life and/or extreme damage to property and create severe disruption to human activities

Slide 4-5: What is a plate?

- The lithosphere is made from the Earth's crust and the very upper part of the mantle. The lithosphere is solid rock which is rigid and brittle, so it can buckle and break. Earthquakes occur in the lithosphere because it is brittle and can fracture when stresses accumulate.
- Beneath the lithosphere is a layer of solid rock called the asthenosphere. This is solid rock but it is plastic and can flow – a bit like chocolate in a warm room.
- Because the Earth is a sphere, the lithosphere is broken up into huge slabs (a bit like a giant jigsaw puzzle) called plates. These plates move around in relation to one another on top of the more ductile asthenosphere.

Slide 6: Where do earthquakes happen?
Map showing the Earth's plate boundaries (redlines) and the location of major earthquakes. Earthquakes are heavily concentrated around plate boundaries and rarely occur within plates.

Slide 7-10: How do earthquakes happen?

- The edges of tectonic plates are jagged and rough. This means that when they push and grind past each other at plate boundaries, they generate lots of friction. Sometimes blocks of rock can become locked together. When this happens, the plates get stuck together the energy that would normally cause the blocks to move past each other is stored up. Eventually the stress builds up so much that the plates suddenly jolt into a new position. This movement releases vibrations called seismic waves which travel through the Earth, shaking the surface, including anything on it. This is an earthquake.
- **Go through slides 7-10 again if needed to show the earthquake happening**
- The point at which the earthquake occurs below the Earth's surface is called the focus, the point directly above the focus on the Earth's surface is known as the epicentre.

Slide 11-12: Transform Boundaries

- Transform plate boundaries, also known as conservative plate boundaries, occur at the edges of plates that are sliding past each other, either in opposite directions or in the same direction but at different speeds.
- Shallow focus earthquakes occur at transform boundaries as plates jolt past each other.
- The San Andreas Fault marks a transform boundary between the North American and Pacific Plates. The fault is 1300 km long, extends to at least 25 km in depth, and has a north west-south east trend. It is classified as a right lateral (dextral) strike-slip fault. The Pacific plate is moving North West, due to sea floor spreading from the East Pacific Rise. The North American plate is also

moving north west (due to sea floor spreading from the Mid Atlantic Ridge) but at a slower speed, so the RELATIVE movement of the North American Plate is to the South East. The average rate of movement along the San Andreas Fault is between 30mm and 50mm per year over the last 10 million years. If current rates of movement are maintained Los Angeles will be adjacent to San Francisco in approximately 20 million years.

Slide 13 - 14: Convergent boundaries- Oceanic-Continental, Oceanic-Oceanic

- When an oceanic plate is moving towards a continental plate, at a convergent plate boundary, the denser oceanic plate (~2.9 g/cm3, basalt in composition), will sink beneath the more buoyant continental plate (~2.7 g/cm3, granite in composition) in a process known as subduction.
- The same process will occur when two oceanic plates converge. The older, colder oceanic plate will be denser and so will be the one subducted beneath the younger warmer and more buoyant plate.
- During subduction the descending oceanic plate drags against the overlying plate, causing both to fracture and deform.
- This results in frequent earthquakes that get deeper as the oceanic plate descends further. This defines an inclined narrow zone of earthquake foci known as the Wadati-Benioff zone which can extend to more than 600km in depth. The dip of the Wadati-Benioff zone coincides with the dip of the subducting plate, different plates may have shallower or steeper Wadati-Benioff zones depending on the angle of the subduction plate.

Slide 15: Convergent Boundaries - Continental-Continental

- When two continental plates collide at a convergent boundary they will ultimately form a wide mountain belt like the Himalaya.
- Because continental plates are thicker and more buoyant than oceanic plates, subduction is largely prevented during continental collision. Compressional stresses cause extensive folding and faulting of rocks within the two colliding plates. This deformation causes the crust to thicken and can extend hundreds of miles into the plate interior, causing a broad zone of shallow earthquakes (no Wadati-Benioff zone).

Slide 16: Divergent Boundaries

- Divergent plate boundaries are sites where new oceanic crust is created by sea floor spreading. Divergent boundaries eventually generate mid ocean ridge systems like the Mid Atlantic Ridge (slow spreading ridge) and the East Pacific Rise (fast spreading ridge). Shallow earthquakes less than 30km in depth are common at spreading ridges and are usually restricted to a narrow zone close to the spreading ridge.
- Developing divergent boundaries like the East African Rift Valley (Nubian plate is pulling away from Somalian plate) have shallow earthquakes on extensional faults form crustal thinning

Slide 17: Body Waves – P Waves

- When an earthquake happens it releases vibrations which travel outward from the focus in every direction. When these vibrations reach the surface they cause the ground to shake. The vibrations travel as waves of energy known as seismic waves. Seismologists (earthquake geologists) measure these seismic waves at different stations around the Earth to work out where an earthquake has occurred. There are a few different types of seismic waves and they move in different ways.
- P waves are a type of body wave – one that moves through the interior of the Earth. P waves travel through solids and liquids and can therefore travel through the Earth's liquid outer core and through water as well as through the Earth's rocky layers. They travel through the Earth by pushing and pulling rocks in the direction they are travelling. P waves can also be known as compressional waves because of this pushing and pulling motion. P waves are the fastest travelling seismic wave and are the first to be detected at a seismic station after an earthquake has occurred.
- **Demonstrate with a slinky OR watch the first part of this YouTube video** https://www.youtube.com/watch?v=v2xhHRQkbNg Get two students to hold either end of a slinky (metal ones are best). To demonstrate a P- wave one student needs to push the end of the slinky towards the other student.

Slide 18: Body Waves – S Waves

- A second type of body wave is known as an **S wave,** these waves move from side to side or from up to down as they go forward. S waves can't travel through liquids so they can't travel through the Earth's outer core which is made from liquid metal. It is this property of S waves that led geologists to work out that the Earth's outer core is liquid rather than solid.
- S waves travel more slowly than P waves so arrive later at seismic stations.
- **Demonstrate with a slinky OR watch the second part of this YouTube video** (https://www.youtube.com/watch?v=v2xhHRQkbNg) Get two students to hold either end of a slinky (metal ones are best). To demonstrate an S wave one student move the slinky from side to side horizontally.

Slide 19: Surface Waves

- **Surface waves** are a third type of seismic wave (two types of surface wave: Rayleigh waves and Love waves). They only travel through the Earth's crust away from the focus in all directions. They move from side to side and up and down.
- Surface waves arrive after both P and S waves and are a much lower frequency wave so can be distinguished on a seismometer. It is surface waves that are almost entirely responsible for the damage and destruction associated with earthquakes. **Click to show building damage**

Slide 20: Seismometers

- Seismologists measure seismic waves using instruments called seismometers. In the past, seismometers worked by having a pen suspended on a weight that then drew a line onto a rotating drum covered with graph paper. When the ground shook in an earthquake, the drum would move up and down and the pen would draw on the rotating drum. The more the ground shook the greater the amplitude and frequency of the wave.
- Today geologists use seismometers which operate using a similar process but instead of pen and paper they use electromagnets which generate a voltage when there is an earthquake and this voltage is then transmitted to a computer display.
- The strength or size of an earthquake is called its magnitude. The bigger the earthquake, the more energy released and the bigger the earthquake's magnitude. An earthquake with a large magnitude will make the Earth's surface shake more and usually cause more damage than a smaller magnitude earthquake.

Slide 21- 22: Locating an Earthquake

- As well as working out the magnitude of the earthquake is geologists also need to work out where the epicentre of the earthquake was. They do this by looking at the P, S and surface waves. S waves travel slower than P waves which means that the further you are away from the earthquake the more spread apart these two waves will be on your seismometer.
- The P- S wave time interval allows seismologists to work out how far away the earthquake occurred from their seismometer.

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- Imagine an earthquake has happened in the UK – stations around the country are set up to measure seismic waves. From the seismometers, the distance from the earthquake to the recording station is calculated by the time difference between the P and S waves.
- **Click for Station 1.** Station 1 in Newcastle detected seismic waves on their seismometer – they used the difference in time between the P and S waves to work out that an earthquake occurred 200km away but they do not know in which direction. The earthquake could have occurred at any point on the blue line.
- **Click for Station 2.** Station 2 in Belfast detected seismic waves on their seismometer too – the P and S waves they detected were slightly closer together than those detected in Newcastle. They worked out that an earthquake occurred 125km away from them. We now have two cross overs one in west Scotland and one in North Wales so we have 2 possible locations for our earthquake.
- **Click for Station 3.** Station 3 in Cardiff also detected seismic waves. The P and S waves they detected were even closer together so the earthquake must have been closest to Cardiff out of the

three cities. We now only have one spot which overlaps each of the circles so this is where the earthquake must have happened!
- You need at least 3 seismic stations to be able to locate and earthquake epicenter.

Slide 23-25: Moment Magnitude Scale
- The size of an earthquake is called its magnitude – the bigger the magnitude the more energy released. The Richter scale is not used anymore to measure magnitude (even though news websites sometimes still report it!) instead the Moment Magnitude Scale is used which is a more accurate measure of earthquake size.
- The Moment Magnitude Scale is logarithmic - an increase of 1 step corresponds to a $10^{1.5}$ (about 32) times increase in the amount of energy released, an increase of two steps corresponds to a 10^3 (1,000) times increase in energy. An earthquake of M_w of 7.0 releases about 32 times as much energy as one of 6.0 and nearly 1,000 times that of 5.0.
- The biggest earthquake ever recorded was in Chile in 1960 with a magnitude of 9.6.

Slide 26: Modified Mercalli Scale
- The effect an earthquake has on the Earth's surface is called its intensity.
- The intensity of an earthquake measured using the 12 point Modified Mercalli Scale which is a qualitative way of measuring the damage caused by earthquakes. It uses shaking and damage reports to describe earthquake impacts.
- The lower numbers of the intensity scale generally deal with the manner in which the earthquake is felt by people, higher numbers deal with structural damage to buildings. Structural engineers usually contribute information for assigning intensity values of VIII or above.

Slide 27-29: Earthquake proofing
- Over a million people have died in earthquakes over the last two decades from collapsing buildings. Engineering buildings to withstand earthquakes is crucial in earthquake prone regions. Slide shows few buildings that have been specifically designed to withstand earthquakes.

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- **Watch Economist YouTube video 'how to make a building earthquake proof'** **https://www.youtube.com/watch?v=sxpi9A7_syE**
- All buildings can carry their own weight otherwise they would fall down by themselves. They can resist some up-and-down loads however side –to side loads and causes the worst damage during an earthquake.
- Buildings can be designed from scratch with earthquake resistant engineering in mind (expensive) or older buildings can be retrofitted to incorporate earthquake resistant engineering (less expensive)
- Cross bracing – diagonal supports in a X shape helps to provide strength and stop building from twisting
- Sheer walls – concrete walls with steel bars helps to reduce rocking motion
- Base isolation/shock absorbers - Rubbery devices are installed near the foundation of the building to absorb the energy from an earthquake, preventing it from dissipating throughout the frame
- Mass dampener - device mounted in structures to reduce the amplitude of mechanical vibrations. The Taipei 101 tower has the world's biggest mass dampener sphere at 660-tonnes. It is suspended from the 92nd to the 87th floor and is a pendulum that sways to offset movements in the building caused by strong gusts and earthquakes.

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- Other things to consider include: Building shape – symmetrical, pyramid shapes are much less likely to collapse – Japanese pagodas, automatic shutters and windows made from shatter proof glass, automatic shut off for gas and electricity to prevent fires, secure bookshelves and other heavy objects to walls and floor, open areas for safe evacuations, good road access, earthquake safety training.

Slide 30: Earthquake proof building activity
Activity sheet available at www.geolsoc.org.uk/Education-and-Careers/Resources/Activity-Sheets-And-Presentations
You will need lots of paper straws or lollipop sticks, card and masking tape. In groups students should create an earthquake resistant structure from their materials. The structure must be at least 30cm tall, have three floors and each floor must support a weight (numeracy blocks, scientific weights, placticine whatever you can find!). Place structure on a tray/ shake table and test how earthquake resistant each groups structure is. Structures with wide bases, solid foundations, symmetrical designs and cross bracing supports (two diagonal supports in an X shape) are likely to withstand the 'earthquake' better.

Slide 31-35: Case Study- Tohoku Japan

- The islands of Japan lie at a point where four major tectonic plates meet: the North American, Eurasian, Philippine and the Pacific plate. Over millions of years these tectonic plates have been moving around and the Pacific plate is slowly being pushed underneath Japan. This means that Japan has had a long history of earthquakes, volcanoes and associated tsunamis.
- In 2011 and earthquake occurred in Tohoku in Japan which resulted one of the most costly natural disasters of all time.

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- The earthquake occurred in the ocean 72 km off the coast of the Tohoku region of Japan (yellow on the map) on the 11 March 2011 at 14:46 local time.It was a magnitude of 9 making it one of the largest ever earthquakes recorded. Because earthquake occurred beneath the sea it triggered a tsunami that was 39 m high when it hit the coast of northern Honshu, the largest island of Japan.
- The tsunami caused widespread flooding, destroyed buildings and shutdown the Fukushima nuclear power station (more next slide).
- Japan's earthquake early warning system gave Tokyo residents 1 minute of warning before earthquake struck. High-speed trains and factory assembly lines were stopped potentially saving thousands of lives.
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- People across Japan received texted alerts of the earthquake and tsunami warnings on their phones so they could try and get to safety.
- As a result of the earthquake and tsunami 15,894 people died, over 6000 were injured and 230,000 people were left homeless. This natural disaster cost the Japanese government $235 billion dollars.
- 400km of Japan's northern Honshu coastline dropped by 0.6
- The earthquake shifted Earth on its axis of rotation and shortened the length of a day by about a microsecond.

Next slide: Fukushima Daiichi Nuclear power station

- Flood waters from tsunami shut down electric power to the Fukushima Daiichi nuclear power station which caused a cooling system failure and meltdown of the radioactive cores. Harmful radioactive materials were released into the sea water. People within 20km of the power station were evacuated those living within 20-30km were advised to stay indoors

Slide 36-33: Case Study- Gorkha, Nepal

- For the past 50 million years, the Indian plate has been travelling northwards into the Eurasian plate. This collision has caused the land to crumple, building the Himalayas, the largest mountain chain currently on Earth. As India moves into Eurasia, friction causes stress to build up. The stress is released when the plates suddenly move. These earthquakes greatly affect the countries of the Himalayas, such as Nepal, India and Pakistan.
- In 2015 an earthquake struck the Gorkha region of Nepal.

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- The earthquake occurred on the 25 April 2015 at 11:56 local time. It had a magnitude of 7.8.
- Almost 9000 people were killed in the earthquake however this death toll may have been minimized by the fact that most villagers were outdoors working when the quake hit meaning that they were not crushed by falling buildings, and also because the earthquake hit on a Saturday which meant that children and teachers were not inside the collapsing school buildings.

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- At Mount Everest, the earthquake resulted in an avalanche at base camp which killed 22 people, making it the deadliest day in Everest history.
- Because Nepal is a very poor country the effects of the Gorkha earthquake will affect its economy for many years to come. Since the earthquake UNESCO has helped to rebuild damaged sites with extra reinforcements to protect them from future earthquakes. Other public buildings such, as schools, are also being built with earthquakes in mind and students are receiving disaster emergency training so that they know how to react should another earthquake occur.

Slide 40-43 : Case Study- Haiti

- Haiti lies on a conservative or transform boundary between the Caribbean plate and the North American Plate. Haiti is a very poor country with a GDP of $739 per person therefore earthquakes have catastrophic effect the country's economy and loss of life.

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- At 16:53 on January 12th 2010 the island of Haiti was struck by a powerful 7.0 magnitude earthquake which occurred 25km east of the capital city Port-au-Prince. The earthquake occurred 13km below the surface on the Enriquillo-Plantain Garden Fault which slipped 1.8m over a distance of 65km.
- The earthquake devastated large parts of the capital Port-au-Prince and resulted in massive loss of life making it one of the most destructive earthquakes of all time.
- 180,000 homes and 5000 schools were damaged or destroyed. The international airport was unusable as the control tower was badly damaged. A lack of building regulations meant that buildings in Haiti were built with poor quality, cheap materials and these simply crumbled when the earthquake struck.

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- 230,000 people were killed and 1.5 million people were made homeless. Homeless people had to live in 1100 squalid camps with limited services such as water and sanitation for over a year. Cholera claimed the lives of several hundred people mainly children.
- Service such as electricity, water , sanitation and communications were badly disrupted or destroyed.
- Total damage bill was around $11.5 billion.

Summary

- Earthquakes are vibrations caused by the movements of the Earth's tectonic plates. They occur when stresses built up in tectonic plates are suddenly released.
- Earthquakes occur at plate boundaries.
- Earthquakes release seismic waves – P waves, S waves and surface waves which are measured using a seismometer
- The Moment Magnitude Scale measures the magnitude of an earthquake – quantitative
- The Modified Mercalli Scale measures the intensity of an earthquake – qualitative
- Buildings can be designed or retrofitted to be more resistant to earthquakes