Meteorite Impacts – KS5 Lesson

Learning Objectives	Curriculum Links
An impact crater is a depression on a rocky body (planet, moon, asteroid) formed by impact of a smaller body, usually a meteorite. Impact craters are found on all rocky bodies, including the Earth, the Moon, Mars and Mercury.	Physics (Astrophysics/Space Physics)
There are four main crater features (rims, walls, floor, and ejecta). In larger craters, other features may be present (for example, a central peak or terraced walls).	Physics (Collisions)
There are 3 stages in crater formation: compressional stage (a small depression forms due to the speed of the impact and conservation of energy between meteorite and planet), excavation stage (immediately after the impact, the impacted area depressurises, which leads to excavation of the bedrock) and modification stage (optional stage where a central peak or terraced walls may form).	Physics (Force, Energy, Waves, Collisions)
Meteorite impacts can modify the bedrock – rocks can melt, get compressed, or break. These rocks are called impactites, and they are a type of metamorphic rock.	Geology (Minerals & Rocks, The Rock Cycle)

Samples needed:

- 3D crater samples (samples 1-8)
- Impact rocks: bicolite (sample 22), Libyan desert glass (sample 23), suevites (samples 24, 25)
- Hand lenses
- Handouts

Lesson length: 50 minutes / 60 minutes with optional module

Lesson Plan

Type/ Slide	Geology	Teaching/Learning activity	Time
Core/ 1 - 4	An impact crater is a depression on a rocky body (planet, moon, asteroid) formed by impact of a smaller body, usually a meteorite. Impact craters are found on all rocky bodies, including Mars, Mercury and the Moon. We also have impact craters on the Earth (e.g. the Barringer crater in Arizona). Some famous craters: Tycho or Copernicus (Moon), Gale (Mars), Chicxulub ("dinosaur crater", Earth).	*Introduce the concept of an impact crater* ***Play up to a minute of NASA video of the Moon, highlighting craters formed from meteorites.*** ***Ask the students if they can name a planet which has impact craters? Do they know the name of a crater in the Solar System?***	5 mins
Core / 5 - 6	There are four main crater features: - Crater **rims**: the edges of a crater, which is elevated from the surrounding topography because of excavated material - Crater **walls**: the interior sides of a crater, usually steep - Crater **floor**: the bottom of a crater, usually flat or bowl-shaped - **Ejecta**: material excavated and thrown out of a crater, usually forming outward-radiating rays surrounding a crater	***Activity 1: studying crater features*** *Divide students into 3-4 groups and hand out tactile samples.* *Show images of craters on the slides.* ***Ask students to identify main crater features****: crater rims, walls, floor, ejecta rays* ***Ask students to do the exercise on the activity sheet.*** *(Physics A level: pick a crater and estimate the mass of the impactor* *Geology A level: pick a crater and calculate its diameter)*	10 mins
Core / 7 - 8	Broadly speaking, an impact has 3 stages: **1. Compressional stage** When a meteorite (impactor) approaches a planet, it moves at very high speed (higher than the speed of sound), and has a lot of kinetic energy. On impact, energy is conserved and the kinetic energy transfers to the planet. The kinetic energy of the impactor is now 0 because it is stationary. The portion of the planet that is impacted wants to "move away" because it now has high kinetic energy. However, the entire planet is unlikely to move (unless the impactor is really large, like in Moon-forming impact), so the kinetic energy manifests as a collisional shockwave propagating away from the impact. Any energy that can't be accommodated as movement will be converted to heat (there is a lot of heating!). The result of the	*Show sketch or photo of a crater with features annotated.* ***Explain how the features formed in the context of collision physics***	10 mins

	compressional stage is relatively small hole, which happens very quickly. *A note for students taking Physics*: a shock wave is a longitudinal wave (the oscillation is to and from source, in the direction of travel). **2. Excavation stage** Immediately after the compression, the impacted area depressurises, leading to massive excavation of material from the impact area. The opposite of a shockwave happens: a wave travels in the opposite direction than the shockwave (here, upwards through the atmosphere or space), and because it has so much space to expand and little resistance, it leads to a large amount of material being excavated, forming a crater. This is essentially an explosion, and it's the reason why most craters are circular. The excavated material is initially fine debris, vapour and melt droplets, and after that, a cone-shaped curtain of ejecta spreads upwards and outwards, forming **rays of ejecta**. **3. Modification stage** This stage leads to further changes to a crater due to really powerful impacts. They lead to the formation of complex crater features (see next section)**.**		
Core - 9	Complex features: - **Central peak(s)**: peaks formed in the central area of a large crater. They form when the impact is so powerful that the area in the middle rebounds after the impact, when the pressure of the impact is gone - **Terraced walls**: sometimes, the walls become too steep to remain stable, so they can form several terraces - **Multiple rings**: Very large craters (termed impact basins) can have as many as 5 or 6 circular rings of mountain chains surrounding the main crater. Their formation is not fully understood, but one proposed theory is that the central peak is so large that it becomes unstable, collapsing to form several rings. An example of a multi-ring basin is Mare Orientale on the Moon.	***Ask students if they saw any crater features other than the ones above?*** *Explain formation of more complex features. If you are running out of time, prioritise the central peak explanation and leave the others*	5 mins

	All these features happen in an optional third stage of crater formation (**the modification stage**).		
Core/ 10	In a powerful impact, the impacted rock undergoes changes due to the shock and heating. The changes often include impact melting (extremely fast melting due to the heating from the impact) following by rapid redistribution of molten material, forming unique crystalline and glassy features. Rocks also get shocked and broken up, forming impact breccias. Rocks created or modified by impacts are called impactites. We will look at 2 types today: **1. Impact glasses** • Formed when rock melts, gets thrown out of a crater and cools very quickly in the air. • Usually found in the **ejecta** outside the crater. **2. Impact breccias** • Breccia = rock containing broken up fragments of other rocks. • Formed when the bedrock is fragmented by the force of impact. It can contain molten or glassy bits, especially closer to the initial impact. • Usually found inside a crater. **Note to teachers**: this is highly simplified, and in reality, impactites are quite complex. Here are a few things we omitted for simplicity: • Impact glasses can be found inside craters if that is where they fell, or if sedimentary processes brought them back into the crater. • Equally, impact breccias are not only found inside craters. It's possible for them to be thrown out of the crater as ejecta too. Some might also be underneath the crater, if they impact fractured the bedrock. • There are types of impactites not mentioned here: - Impact melts = rocks that melt completely because of an impact. If they cool down slowly, they don't become glassy, instead resembling igneous rocks (even though their impact origin makes them metamorphic). Impact glasses are a subtype of impact melts. Shocked rocks = rocks affected by shock metamorphism. Shocked rocks don't melt or brecciate, but the pressure and heat of an impact	***Ask students what do they think happens to a rock when it is hit by a meteorite?*** *(Answers: it melts, it gets squashed, it gets broken up etc)* ***Introduce the two types of impactites that they will look at next.***	5 mins

	causes different minerals and textures to form through shock metamorphism.		
Core / 11	In this activity, students look at some rocks that come from impact craters on Earth, and they make basic rock descriptions. Rocks can be described based on their physical characteristics, including: • Colour(s) • Does it contain grains, crystals or clasts? • Size of grains/crystals/clasts • What does the outside look and feel like? (smooth, rough, shiny, glassy, pitted?) • Other features Don't forget to look closely using hand lenses or magnifying glasses! **Differentiation suggestion:** If you are short on time, we would recommend reducing the number of rocks to 1 impact glass and 1 impact breccia.	***Activity 2: Impact rock handling*** *Set up 4 rock stations around the classroom and ask students to circulate the room to look at each rock.* *Alternatively, pass the rocks around. Ideally, each pupil can look at one glass and one breccia.* ***Think about the rock cycle – what type of rock (sedimentary, igneous or metamorphic) do you think these rocks are?*** *(Answer: metamorphic, because they are modified by the heat and pressure of an impact).*	10 mins
Core / 12 - 17		*Start showing slides with the answers. For each rock, go through the observations, ask students if they noticed anything extra, and say what the rock is.* ***Think about the rock cycle and the characteristics of each rock type – what type of rock (sedimentary, igneous or metamorphic) do you think these impact rocks are similar to?*** *(Answer: metamorphic, because they are modified by the heat and pressure of an impact.)*	5 mins
Optional / 18	There are a few reasons why there are so few craters on the Earth compared to other bodies. Firstly, it's important to note that large meteorite impacts are rare nowadays, but they were very common early in the Solar System, simply because there were more asteroids back then. This is because collisions between small rocky bodies are essential to form planets. The Earth and the other planets probably experienced a similar number of impacts, but on the Earth, they were erased due to several reasons: - **Tectonics** and **the rock cycle**: plate tectonics and reprocessing of the Earth's crust mean that the rocks on the surface of the Earth now are not the same as early in the planet's history, so craters were buried or destroyed. The Moon has no tectonic activity.	*Ask students to imagine a full moon in as much detail as they can. At the very least, the moon will include white areas and grey areas (the grey areas are formed by impacts too), and some of them may even have put some craters on.* ***Can they think of a crater on the Earth?*** *(Answer: probably not, or they may say the dinosaur crater, but that's buried in rock.)* ***Ask students why are there more craters on other planets and on the Moon than on the Earth?*** *Discuss how the factors influence crater exposure.*	10 mins

	- **Water**: unlike all other planets in the Solar System, the Earth's surface is 70% covered by water, which erased most craters or may have prevented them from forming in the first place. - **Vegetation**: more recent craters may be covered by vegetation.		