Unit 15

Answers: Geology

Quick checks

1 c Paleontology (from Greek *palaios*, old, and *on*, a living thing) is the study of fossils and the life of the past. Petrology studies rocks, seismology earthquakes and mineralogy minerals.

2 a At a divergent boundary the plates move apart, the mantle beneath melts as the pressure on it drops, and the magma fills the gap, cools and becomes new crust. At a convergent boundary crust is destroyed or piled up, and at a transform boundary it is neither made nor destroyed.

3 d The Tethys Himalaya, north of the main peaks, is made of limestone, shale and sandstone from the floor of the old Tethys Sea, lifted without being changed much by heat, so its fossils survive. In the Higher Himalaya the rock was changed so deeply by heat and pressure that fossils were destroyed.

4 b Gas dissolved in magma comes out as bubbles as the magma rises. In runny magma the bubbles escape easily and the lava flows out quietly. Sticky (silica-rich) magma holds the bubbles in, so the pressure builds until it bursts out all at once, like a shaken bottle of soda opened suddenly.

5 c Most injuries come from falling things and from running while the ground shakes. Taking cover under a strong table protects you from falling objects. In modern houses a doorway is no stronger than the rest of the house and its door can swing into you, and a lift may stop between floors.

1 a. **c** The lithosphere, the stiff crust and topmost mantle, about 100 km thick, is broken into plates, which slide on the soft asthenosphere below.

1 b. **b** India, on the Indian (Indo-Australian) plate, moved north and hit Asia, on the Eurasian plate, about 50 million years ago. The collision continues today.

1 c. **a** An anticline is an upfold, an arch; a syncline is a downfold, a trough. The limbs are a fold's sloping sides, and a fault is a break along which rock has moved.

1 d. **d** A recumbent fold (Latin *recumbere*, to lie down) has been pushed over so far that its axial plane is almost horizontal. In an overturned fold, one limb is past upright, but the fold doesn't yet lie flat.

1 e. **b** Melted rock underground is magma; once it flows out on the surface it is called lava. Ash is fine broken rock thrown out by an eruption, and pumice a light, frothy rock that forms when lava full of gas cools.

1 f. **b** A volcano that hasn't erupted for a long time but could erupt again is dormant. Fuji is also a composite volcano, not a shield volcano.

1 g. **b** The focus, or hypocenter, is where the rock slips underground; the epicenter is the point on the surface straight above it.

2 a. The rocks of the high Himalaya, especially the Tethys Himalaya, were laid down as mud and lime on the floor of the Tethys Sea between India and Asia, and the shells of sea animals, such as ammonites, were buried in them. When India collided with Asia, about 50 million years ago, these layers were squeezed, folded and pushed up thousands of meters. So the sea animals' fossils, like the shaligrams of the Kali Gandaki, now lie high in the mountains.

2 b. Nepal lies where the Indian and Eurasian plates, both carrying continents, collide. Continental crust is too light to sink deep into the mantle, so no wet ocean plate goes down to release water and melt the mantle, and there are no ridges or hot spots here. So no magma forms and there are no volcanoes. But the crust is squeezed, and the stuck fault under Nepal slips from time to time, so there are many earthquakes.

2 c. At the boundaries, plates move apart, push together or slide past each other. Where they part or where sea floor sinks, the mantle melts and magma rises, making volcanoes; where they push or slide, the rock along the faults is stuck, bends and then slips, causing earthquakes. The middle of a plate moves as one rigid block, so little happens there.

2 d. Nepal lies over the stuck fault between the Indian and Eurasian plates, so big earthquakes come every century or two. Its steep, young mountains bring down landslides when shaken, and the soft lake-bed soil of the Kathmandu valley makes the shaking worse in places. Many houses are heavy buildings of stone, brick or mud not tied together, or concrete buildings without enough steel, which fall on the people inside.

2 e. Most people die when buildings collapse on them. The building code says how to make a building stand up to shaking: a firm foundation, walls tied together by reinforced bands, steel joining columns and beams, a light roof fixed to the walls and a regular shape. A building that stays standing, even if cracked, protects the people inside, so fewer die.

3 i.

Anticline	Syncline
An upfold: the layers arch up.	A downfold: the layers sag down.
The layers slope down away from its middle.	The layers slope down towards its middle.
Its highest point is the crest.	Its lowest point is the trough.
The oldest rock is in its middle (core).	The youngest rock is in its middle (core).

3 ii.

Magma	Lava
Melted rock under the Earth's surface.	Melted rock that has come out on the surface.
Collects in a magma chamber under a volcano.	Flows out of a vent or crack.
Holds a lot of dissolved gas.	Has lost much of its gas.
Cools slowly underground into rocks like granite.	Cools quickly on the surface into rocks like basalt.

4 a. Geology is the study of the Earth: what it is made of, its structure, the processes that change it and its history. Its study is important for Nepal because:

a. it helps find minerals, groundwater and building materials, such as the limestone used for cement;
b. it shows where and how roads, tunnels, dams and hydropower projects can be built safely on Nepal's steep, broken rock;
c. it maps faults, weak slopes and dangerous glacial lakes, to reduce the harm of earthquakes, landslides and floods.

4 b. Tectonic plates are the large pieces into which the Earth's lithosphere (the crust and the topmost mantle, about 100 km thick) is broken. They move slowly, 2–10 cm a year, over the soft asthenosphere. Four major plates: the Pacific, the Eurasian, the Indian (Indo-Australian) and the African plates (also the North American, South American and Antarctic plates).

4 c.

a. **Divergent**: plates move apart; magma rises into the gap and makes new crust, forming mid-ocean ridges and rift valleys. Example: the Mid-Atlantic Ridge, which rises above the sea in Iceland.
b. **Convergent**: plates move towards each other. Where sea floor meets a continent, it sinks under it (subduction), making a trench and a line of volcanoes, as in the Andes. Where two continents meet, the crust crumples into fold mountains, as in the Himalaya.
c. **Transform**: plates slide past each other, causing earthquakes but making no new crust. Example: the San Andreas Fault in California.

4 d.

a. **Deposition**: layers of sediment, mud, sand and shells, were laid down for millions of years on the floor of the Tethys Sea between India and Asia, and hardened into sedimentary rock.

b. **Convergence**: the Indian plate moved north towards the Eurasian plate, and the Tethys sea floor sank under Asia, so the sea grew narrower.

c. **Collision and folding**: about 50 million years ago India hit Asia. Continental crust can't sink, so the layers between the two continents were squeezed from both sides, folded into anticlines and synclines, broken along thrust faults and pushed up.

d. **Uplift and erosion**: India keeps pushing at about 4–5 cm a year, so the Himalaya are still rising, while rain, ice and rivers wear them down and carry the sediment to the plains.

The diagram, as in the figure in 15.3: wavy layers with an upfold labeled anticline (crest at the top), a downfold labeled syncline (trough at the bottom), the sloping sides labeled limbs, and a dashed line through each bend labeled axial plane.

4 e. A volcano is an opening in the Earth's crust through which magma, ash and gases erupt, and the mountain built round it. Causes:

a. Magma forms where hot mantle melts: where plates pull apart and the pressure on the mantle drops; where a sinking ocean plate releases water, lowering the melting point of the mantle above; and over hot spots, where very hot rock rises from deep in the mantle.

b. Magma is lighter than the solid rock round it, so it rises and collects in a magma chamber.

c. It contains dissolved gases, mostly water vapor. As it rises, the gas forms bubbles and the pressure in the chamber builds.

d. When the pressure is greater than the strength of the rock above, the magma bursts through to the surface: an eruption.

4 f. Harmful:

a. Lava flows and pyroclastic flows burn and bury houses, fields and forests, and pyroclastic flows kill people, as at Pompeii in AD 79.

b. Ash falls break roofs, ruin crops and water, and harm the lungs; mixed with water they make lahars, which buried Armero, Colombia, in 1985.

c. Sulphur dioxide high in the air cools the climate, as after Tambora in 1815, causing failed harvests.

Useful:

a. Volcanic ash weathers into very fertile soil.

b. The heat near volcanoes gives geothermal energy for electricity and heating, as in Iceland.

4 g.

a. Monitor active volcanoes with seismometers, GPS and gas sensors, so that eruptions can be forecast.

b. Make hazard maps and keep homes, schools and hospitals out of the paths of lava, pyroclastic flows and lahars.

c. Prepare evacuation plans, warn people in time and practice moving them to safe places.

d. Protect against ash: sweep roofs, wear masks, cover water sources and keep aircraft away from ash clouds.

4 h. An earthquake is a sudden shaking of the ground caused by waves of energy released when rock breaks or slips below the surface. By the elastic rebound theory: the rock on either side of a fault is held by friction while the plates keep moving, so it bends and stores energy, like a bent stick, over many years. When the force becomes greater than the friction, the fault slips suddenly, and the rock on both sides springs back to an unbent shape. The stored energy is released as seismic waves, which spread out from the focus and shake the ground.

4 i.

a. Buildings collapse, killing and injuring people and leaving many homeless, as in 2015, when nearly 9,000 died.

b. Heritage is lost: the Dharahara, the Kasthamandap and many temples fell in 2015.

c. Landslides and avalanches bring down hillsides, block roads and dam rivers, as at Langtang in 2015.

d. Roads, bridges, water and power supplies are destroyed, and the economy suffers for years.

4 j.

a. Build houses according to the National Building Code, with ties, bands and steel to hold them together.

b. Retrofit old buildings, especially schools and hospitals.

c. Don't build on steep, loose slopes or soft filled ground; keep open spaces in towns.

d. Fix heavy furniture to the walls, keep an emergency bag, and practice earthquake drills; mark Earthquake Safety Day on 2 Magh.

e. During shaking, Drop, Cover and Hold On indoors; outdoors, move to an open place away from buildings, poles and slopes.

4 k. India is still moving north into Asia at about 4–5 cm a year, and about 2 cm a year of that is taken up across Nepal. India slides under Nepal along a great fault, the Main Himalayan Thrust. Below about 20 km the rock is hot and the fault creeps, but above that it is stuck. So the rock above the stuck part is squeezed and bent like a spring, and the high Himalaya is pushed up. After a century or two, a few meters of slip have built up, and the stuck part slips suddenly in a great earthquake, as in 1934 and 2015. As long as India keeps moving, the strain builds again, so the mountains keep rising and the earthquakes keep coming.

5 a.

$$d = 2.5 \times 10{,}000{,}000 = 25{,}000{,}000 = \frac{25{,}000{,}000}{100{,}000} = 250$$

250 km.

5 b. 1,800 km = 1,800 × 100,000 cm = 180,000,000 cm.

$$v = \frac{180{,}000{,}000}{40{,}000{,}000} = 4.5$$

4.5 cm a year, about the speed of India today.

5 c.

a. Shortening = 50 − 35 = **15 km**, and $\frac{15}{50} \times 100\% = \mathbf{30\%}$.

b. 15 km = 1,500,000 cm, so

$$t = \frac{1{,}500{,}000}{1.5} = 1{,}000{,}000$$

One million years.

5 d. d = 7.0 − 5.0 = 2.

a. $10^2 =$ **100 times** higher.

b. $10^{1.5\times 2} = 10^3 =$ **1,000 times** as much energy.

5 e.

$$\frac{d}{3.5} - \frac{d}{6} = 20 \quad \Rightarrow \quad d \times \frac{6 - 3.5}{21} = 20 \quad \Rightarrow \quad d = \frac{20 \times 21}{2.5} = 168$$

168 km.

5 f. No. The Himalaya are young mountains: they began to rise about 50 million years ago, when India hit Asia, and they are still rising, because India still pushes north. While a range is being pushed up, it can stay high even as rain and rivers wear it down. The Aravalli hills are far older, more than a billion years old: once a great range, they have been worn down for hundreds of millions of years since the push that built them stopped, and are now low hills. Old ranges are low and rounded; young ones are high, steep and sharp, with many earthquakes. Height shows that a range is young and still being pushed, not that it is old.