

CHAPTER 3

Interior of the Earth

CBSE Class 11 · Geography · Fundamentals of Physical Geography · Chapter 3

CBSE · Geography · Class 11

WHAT THIS CHAPTER DOES

A List the direct and indirect sources of information about the earth's interior.

B Define an earthquake's focus, epicentre and the seismograph that records it.

Boards prep that builds confidence, not anxiety.

TODAY'S MISSION

Today's mission

- 1** List the direct and indirect sources of information about the earth's interior.
- 2** Define an earthquake's focus, epicentre and the seismograph that records it.
- 3** Distinguish P-waves from S-waves and explain how the shadow zones reveal a liquid outer core.
- 4** Map the layered structure — crust, mantle, core — with its discontinuities, and outline volcanoes and volcanic landforms.

WHY THIS MATTERS

Why this chapter matters

- 1** It explains the METHOD of physical geography — inferring the unseen from indirect evidence — using the earth's own interior as the case study.
- 2** Worth 5-7 marks, very often as the seismic-wave / shadow-zone long answer plus an MCQ on the layers.
- 3** It is the foundation for plate tectonics, earthquakes and volcanoes — the most exam-heavy themes of Class 11 and of competitive exams alike.

TOPIC

A

How do we know? Sources of information about the interior

TOPIC

Direct and indirect evidence

WHY IT MUST BE MOSTLY INDIRECT

The earth's radius is about 6,370 km, yet the deepest hole ever drilled — the Kola Superdeep Borehole in Russia — reached only around 12 km, barely a scratch. Rising temperature, pressure and sheer cost make deeper drilling impossible today. Because we cannot

DIRECT SOURCES

DIRECT sources give us actual material from the earth, but only from its shallow outer skin. They include deep MINING, which lets geologists examine rocks at depth; deep DRILLING projects such as the Kola Superdeep Borehole and ocean-floor drilling, which bring up cores of rock; and VOLCANIC

INDIRECT SOURCES (NON-SEISMIC)

Several INDIRECT clues, short of seismic waves, also constrain the interior. Temperature, PRESSURE and DENSITY all increase steadily with depth — the rising density shows heavier material lies deeper, hinting at an iron-rich core. METEORITES, thought to be made of

SEISMIC WAVES — THE CHIEF SOURCE

The single most powerful indirect source is SEISMIC WAVES generated by earthquakes. As these waves pass through the earth they speed up, slow down, bend (refract) and sometimes stop whenever they meet a layer of different density or state. By

TOPIC

B

Earthquakes: focus, epicentre and the seismograph

THEOREM · LOAD-BEARING RESULT

Anatomy of an earthquake

An earthquake is the shaking of the earth caused by the sudden release of energy along a fault. The point **INSIDE** the earth where the energy is first released is the **FOCUS** (or hypocentre); the point on the **SURFACE** directly above the focus is the **EPICENTRE**; and the instrument that records the resulting waves is the **SEISMOGRAPH**.

STATEMENT

Energy released at the focus radiates outward as seismic waves. Damage is generally greatest at the epicentre (nearest the source) and decreases with distance. A seismograph records the

WHY THIS MATTERS

- Energy stored as strain in rocks is released in a fraction of a second along a fracture
- Pinpointing the focus and epicentre lets us locate the quake, and recording the waves lets us measure both the quake **AND** the interior they travelled through.

WATCH OUT FOR

NOTE Do not swap focus and epicentre. **FOCUS** = inside the earth (source); **EPICENTRE** = on the surface above it. This is a classic one-mark trap.

TOPIC

C

Seismic waves: P, S and surface waves

TOPIC

The three families of waves

BODY WAVES VS SURFACE WAVES

Seismic waves fall into two broad groups. **BODY WAVES** travel through the interior (the body) of the earth and come in two kinds — P-waves and S-waves. **SURFACE WAVES** travel only along the earth's surface, are generated when body waves reach the surface, move more slowly, arrive

P-WAVES (PRIMARY)

P-waves, or Primary waves, are the **FASTEST** seismic waves and the **FIRST** to arrive at any station — which is how they earned the name 'Primary'. They are **LONGITUDINAL** (push-pull) waves: particles of the medium vibrate back and forth in the same direction the wave travels. Like a

S-WAVES (SECONDARY)

S-waves, or Secondary waves, are **SLOWER** than P-waves and arrive **SECOND** — hence 'Secondary'. They are **TRANSVERSE** waves: particles vibrate at right angles to the direction of travel, like the ripple on a shaken rope. The decisive property of S-waves is that they travel **ONLY** through **SOLIDS**.

WHY THE DIFFERENCES MATTER

The contrast between the two body waves is what turns earthquakes into a tool for X-raying the planet. Because P-waves go through everything but S-waves stop at liquids, the pattern of which waves reach which recording stations — and where they fail to appear — pins

TOPIC

D

**The shadow
zones — the
master clue**

THEOREM · LOAD-BEARING RESULT

The shadow zones of seismic waves

Recording stations on the far side of the earth from an earthquake reveal **SHADOW ZONES** — belts where certain waves fail to arrive. The S-wave shadow zone covers the entire surface beyond about 105 degrees from the epicentre; the P-wave shadow zone is a narrower ring between about 105 and 145 degrees.

STATEMENT

S-waves are recorded only up to about 105 degrees from the epicentre and **NOWHERE** beyond it, because the liquid outer core completely **absorbs (stops) them** — proving the outer core is

WHY THIS MATTERS

- When the body waves hit the liquid outer core, S-waves cannot continue at all (no shearing in a liquid) while P-waves are bent inward
- the geometry of these effects projects 'shadows' onto the far surface where the waves are missing.

WATCH OUT FOR

NOTE The two shadow zones are **NOT** the same. S-shadow = everything past about 105 degrees (the whole far side). P-shadow = only the ring from about 105 to 145 degrees. Saying the P-shadow is 'everywhere past 105 degrees' is the single most common error here.

WORKED EXAMPLE

Reason from the shadow zones to the interior

- 1** Observation 1: S-waves vanish completely beyond about 105 degrees from the epicentre. Since S-waves cannot travel through liquid, conclude: the OUTER CORE must be LIQUID.
- 2** Observation 2: P-waves are missing only in the 105-145 degree ring, then reappear beyond 145 degrees. Conclude: the liquid core REFRACTS (bends) P-waves, casting a narrower ring-shaped shadow rather than stopping them.
- 3** Observation 3: P-waves that pass through the very centre speed up slightly. Conclude: the INNER CORE is SOLID (waves travel faster in solid than in liquid).
- 4** Conclusion: from three wave observations alone, scientists deduced a liquid outer core and a solid inner core — without ever drilling a metre toward them.

TOPIC

E

The layered structure of the earth

TOPIC

Crust, mantle and core

THE CRUST

The CRUST is the thin, solid, outermost shell of the earth and the only layer we can directly sample. It is not uniform: the CONTINENTAL crust is thicker — about 30 km on average, swelling to 60-70 km beneath mountains — and lighter, dominated by silica and aluminium ('SIAL', broadly granitic). The OCEANIC

THE MANTLE

Below the Moho lies the MANTLE, reaching down to about 2,900 km and forming the largest share of the earth's volume. The mantle is dense silicate rock and is overwhelmingly SOLID — the fact that S-waves pass right through it confirms this. However, its upper portion contains the

THE CORE

The CORE lies below about 2,900 km and reaches the earth's centre at about 6,370 km. It is made mainly of IRON and NICKEL, a composition often abbreviated 'NIFE'. The core has two parts. The OUTER core is LIQUID — this is precisely why S-waves cannot cross it and why their shadow

THE DISCONTINUITIES

The boundaries between layers, where seismic-wave speeds change abruptly, are called DISCONTINUITIES, each named after the scientist who found it. The MOHOROVICIC (Moho) discontinuity separates the crust from the mantle. The GUTENBERG discontinuity separates the mantle from the

TOPIC

F

Volcanoes and volcanic landforms

TOPIC

Volcanoes and the forms they leave behind

WHAT A VOLCANO IS

A VOLCANO is a vent in the earth's crust through which molten rock (MAGMA below the surface, LAVA once it erupts), gases, ash and rock fragments are ejected. The molten material rises from a MAGMA CHAMBER through a central PIPE or VENT and emerges at a CRATER (or, when very

TYPES OF VOLCANOES

Volcanoes are classified by their eruptions and shape. SHIELD volcanoes (e.g. the Hawaiian volcanoes) are broad, gently sloping cones built by runny, low-silica basaltic lava that flows far before solidifying. COMPOSITE or strato-volcanoes (e.g. Fujiyama, Vesuvius) are tall, steep, layered cones built by

EXTRUSIVE LANDFORMS

EXTRUSIVE (volcanic) landforms are those built by material that erupts and solidifies ON the surface. They include the various volcanic cones described above, extensive LAVA FLOWS and LAVA PLATEAUS formed when fluid basalt spreads over large areas (the Deccan Traps being the classic Indian

INTRUSIVE LANDFORMS

INTRUSIVE (plutonic) landforms form when magma cools and solidifies BENEATH the surface, before reaching open air; they become visible only later, once erosion strips away the overlying rock. The main intrusive forms are the BATHOLITH (a huge dome of solidified magma deep in the crust

THEOREM · LOAD-BEARING RESULT

Intrusive vs extrusive — the cooling rule

“ The depth at which magma solidifies decides both the landform and the rock texture. **EXTRUSIVE** igneous activity solidifies **AT** the surface as lava, cooling fast into fine-grained rocks (basalt) and volcanic cones / flows. **INTRUSIVE** igneous activity solidifies **BELOW** the surface, cooling slowly into coarse-grained rocks (granite) and forms such as batholiths, laccoliths, sills and dykes.

STATEMENT

Fast cooling at the surface gives little time for crystals to grow, producing fine-grained **EXTRUSIVE** rocks and landforms (lava flows, plateaus, cones). Slow cooling at depth allows large crystals

WHY THIS MATTERS

- Crystal size depends on cooling rate: the slower the cooling, the larger the crystals
- Surface lava cools in air/water within hours to years
- deep magma may take thousands of years, so its crystals grow large.

WATCH OUT FOR

NOTE Match each landform to the right side: batholith / laccolith / sill / dyke are **INTRUSIVE** (underground); lava flows, plateaus and volcanic cones are **EXTRUSIVE** (surface). Mixing the two lists is a common mark-loser.

TOPIC

How we know the interior

TRAP → TRUTH

× **MISTAKE** Scientists have drilled to the centre of the earth, so we directly observe the core.

✓ **CORRECT** We have NEVER reached even the bottom of the crust. The deepest hole — the Kola Superdeep Borehole in Russia — reached only about 12 km, a tiny scratch on a 6,370 km radius. Almost everything we know about the deep interior is INDIRECT, inferred chiefly from how seismic (earthquake) waves change speed and direction as they pass through the earth. Direct sources reach only the shallow crust.

TOPIC

P-waves vs S-waves

TRAP → TRUTH

× **MISTAKE** S-waves are faster than P-waves because 'S' is a stronger wave.

✓ **CORRECT** P-waves (Primary) are the FASTEST seismic waves and arrive first; S-waves (Secondary) are slower and arrive second — that is literally why they are named Primary and Secondary. The decisive difference is not strength but MEDIUM: P-waves travel through solids, liquids and gases, whereas S-waves travel only through SOLIDS and cannot pass through liquids. This single fact is the key to the shadow zones and to discovering the liquid outer core.

TOPIC

Shadow zones

TRAP → TRUTH

- × **MISTAKE** The shadow zone is a region where NO seismic waves of any kind are ever recorded.
- ✓ **CORRECT** The two shadow zones are different. The S-wave shadow zone is the whole zone BEYOND about 105 degrees from the epicentre — S-waves never emerge there at all, because they were stopped by the liquid outer core; this proves the outer core is liquid. The P-wave shadow zone is only the BAND between about 105 and 145 degrees — P-waves are merely bent (refracted) away from this band by the core, so they reappear beyond 145 degrees. So the P-shadow is a ring; the S-shadow is everything past 105 degrees.

TOPIC

Focus and epicentre

TRAP → TRUTH

- × **MISTAKE** The epicentre is the place inside the earth where the earthquake starts.
- ✓ **CORRECT** It is the reverse. The FOCUS (or hypocentre) is the point INSIDE the earth where the energy is first released; the EPICENTRE is the point on the SURFACE directly above the focus. Damage is usually greatest at the epicentre because it is nearest the source. Confusing the two is one of the commonest one-mark errors.

TOPIC

The asthenosphere and the mantle

TRAP → TRUTH

× **MISTAKE** The whole mantle is molten liquid magma.

✓ **CORRECT** The mantle is overwhelmingly SOLID rock — S-waves pass through it, proving so. Only the upper part contains the ASTHENOSPHERE, a relatively soft, PLASTIC (semi-molten, ductile) layer from which magma originates and over which the rigid lithospheric plates move. 'Plastic' means it can flow very slowly over long times, not that it is a liquid ocean. The genuinely liquid layer is the OUTER CORE, not the mantle.

TOPIC

The core

TRAP → TRUTH

× **MISTAKE** The whole core is liquid molten iron.

✓ **CORRECT** The core has two parts. The OUTER core is LIQUID (S-waves cannot pass through it — that is how we know), while the INNER core is SOLID despite being the hottest region, because the colossal pressure at the centre keeps it solid. Both are made mainly of iron and nickel (sometimes called NIFE). The liquid outer core's motion also generates the earth's magnetic field.

TOPIC

Crust composition

TRAP → TRUTH

× **MISTAKE** The continental crust and the oceanic crust are made of the same material and thickness.

✓ **CORRECT** They differ. The CONTINENTAL crust is thicker (about 30 km, up to 70 km under mountains) and lighter, dominated by silica and aluminium ('SIAL', granitic). The OCEANIC crust is thinner (about 5 km) and denser, dominated by silica and magnesium ('SIMA', basaltic). The boundary between the crust and the mantle is the Mohorovicic (Moho) discontinuity.

TOPPER TEMPLATE · MARK-BY-MARK

5-mark question: 'Distinguish between P-waves and S-waves and explain how they produce the

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|--|---|
| <p>1 DEFINE BOTH WAVES WITH THEIR KEY PROPERTY
1 m</p> | <p>Open: 'P-waves (Primary) are the fastest body waves; they are longitudinal (push-pull) and travel through solids, liquids and gases. S-waves (Secondary) are slower transverse waves that travel ONLY through solids and cannot pass through liquids.' State the medium difference first — it is the whole answer.</p> |
| <p>2 NOTE SPEED / ORDER OF ARRIVAL
1 m</p> | <p>Add that P-waves arrive first on the seismograph and S-waves second (hence Primary and Secondary), and that both are BODY waves travelling through the interior, unlike the slower, surface-confined surface waves that cause most damage.</p> |
| <p>3 EXPLAIN THE S-WAVE SHADOW ZONE
1.5 m</p> | <p>'Beyond about 105 degrees from the epicentre, NO S-waves are recorded — the S-wave shadow zone covers the entire far side. Because S-waves cannot travel through liquid, their complete disappearance proves that the OUTER CORE is liquid.' Tie the observation to the conclusion.</p> |
| <p>4 EXPLAIN THE P-WAVE SHADOW ZONE + CONCLUDE
1.5 m</p> | <p>'P-waves are recorded everywhere EXCEPT a ring between about 105 and 145 degrees — the P-wave shadow zone — because the liquid core REFRACTS (bends) them away from this band; they reappear beyond 145 degrees. Thus the shadow zones reveal both the existence and the liquid nature of the core.' A clear cause-to-conclusion close earns full marks.</p> |

TOPPER TEMPLATE · MARK-BY-MARK

3-mark question: 'Explain the direct and indirect sources of information about the interior of the

- | | |
|---|--|
| <p>1</p> <p>DIRECT SOURCES</p> <p>1 m</p> | <p>'DIRECT sources come from material we can physically reach: deep mining, deep drilling projects such as the Kola Superdeep Borehole (about 12 km) and ocean-drilling, and the molten material thrown out by VOLCANIC ERUPTIONS, which brings up samples from depth.' Direct sources reach only the shallow crust.</p> |
| <p>2</p> <p>INDIRECT SOURCES (NON-SEISMIC)</p> <p>1 m</p> | <p>'INDIRECT sources include the increase of TEMPERATURE, PRESSURE and DENSITY with depth; the study of METEORITES (similar in make-up to the earth's deep material); and the earth's GRAVITY and MAGNETIC FIELD, whose variations reveal the distribution of mass inside.'</p> |
| <p>3</p> <p>SEISMIC WAVES — THE CHIEF INDIRECT SOURCE</p> <p>1 m</p> | <p>'The most important indirect source is SEISMIC WAVES from earthquakes: their changing speed and bending as they cross different layers, and the shadow zones, reveal the boundaries and physical state (solid/liquid) of the crust, mantle and core.' Naming seismic waves as the chief source secures the mark.</p> |

TOPPER TEMPLATE · MARK-BY-MARK

5-mark question: 'Describe the layered structure of the earth's interior and the

1 THE CRUST
1.5 m

'The CRUST is the thin, outermost solid shell — continental crust about 30 km (up to 70 km under mountains), made of lighter silica-alumina (SIAL, granitic); oceanic crust about 5 km, denser silica-magnesia (SIMA, basaltic). The crust-mantle boundary is the Mohorovicic (Moho) discontinuity.'

2 THE MANTLE
1.5 m

'The MANTLE extends from the Moho to about 2,900 km and forms the bulk of the earth's volume. It is solid rock, but its upper part contains the ASTHENOSPHERE — a soft, plastic layer that is the source of magma and over which the lithospheric plates move.'

3 THE CORE
1.5 m

'The CORE, mainly iron and nickel (NIFE), lies below about 2,900 km. The OUTER core is liquid (S-waves stop here — the Gutenberg discontinuity marks the mantle-core boundary); the INNER core is solid despite extreme heat, kept solid by immense pressure (the Lehmann discontinuity separates outer from inner core).'

4 CONCLUDE
0.5 m

Close: 'These layers — distinguished by density and physical state and separated by seismic discontinuities — were mapped almost entirely from the behaviour of seismic waves.' Naming Moho, Gutenberg and Lehmann earns the discontinuity marks.

PYQ PATTERNS

Top PYQ patterns to drill

#1

Distinguish between P-waves and S-waves / Explain the shadow zones of seismic waves. (3-5 marks)

CBSE SQP 2020, 2022; School Annual recurrently

#2

Explain the direct and indirect sources of information about the interior of the earth. (3-5 marks)

CBSE SQP 2019, 2021; very common at school level

#3

Describe the layers of the earth's interior (crust, mantle, core) and the discontinuities between them. (5 marks)

CBSE SQP 2022; School Annual 2021, 2022

#4

Define focus / hypocentre, epicentre and seismograph. How is an earthquake measured? (1-3 marks)

School Term papers, MCQ + short answer

#5

Distinguish between intrusive and extrusive volcanic landforms / Describe the types of volcanoes. (3-5 marks)

CBSE SQP 2023; School Annual

RECAP · MEMORISE THESE

5-line revision

1 How we know — Interior known mostly **INDIRECTLY** (Kola hole only ~12 km). Chief source = **SEISMIC WAVES**; direct = mining, drilling, volcanic eruptions.

2 The waves — P = fast, all media; S = slow, **SOLIDS ONLY**. S-shadow past 105 deg -> liquid **OUTER CORE**; P-shadow = 105-145 deg ring (refraction).

3 The layers — Crust (SIAL/SIMA, Moho) -> mantle (solid; plastic asthenosphere) -> core (outer **LIQUID** / inner **SOLID**, NIFE; Gutenberg & Lehmann). Volcanoes: intrusive vs extrusive.

WHAT'S NEXT

What's next

- Chapter 4 — Distribution of Oceans and Continents (plate tectonics builds directly on the asthenosphere and lithosphere learnt here).
- Sit the 15-MCQ Quick Drill (companion PDF) — under 20 minutes, target $\geq 12/15$.
- Then the full term-pattern paper — 30 marks, 60 minutes, with model answers.

You can now X-ray a planet.

Sources, seismic waves, shadow zones, layers, volcanoes — locked. Take the drill, sit the paper, beat the chapter.

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Boards prep that builds confidence, not anxiety.