Unit 15 · Geology

STUDY NOTES

Key terms

Geology: study of the Earth: rocks, minerals, structure, processes, history (4.6 billion years); Greek *gē* + *logos*. Branches: mineralogy, petrology, paleontology (fossils), seismology.

Lithosphere: crust + topmost mantle; stiff; about 100 km thick.

Asthenosphere: soft mantle below; solid but creeps.

Tectonic plates: pieces of the lithosphere; move 2–10 cm a year.

Subduction: heavier oceanic plate sinks under another into the mantle; makes a trench.

Fold: bend in rock layers. **Fault**: break with movement. **Thrust**: low-angle fault; sheets pushed over others.

Magma: melted rock underground; **lava** once out. **Vent**: pipe; **crater**: bowl at the top.

Pyroclastic material: ash, pebbles, volcanic bombs; **pumice** floats.

Lahar: mudflow of ash and water.

Earthquake: sudden shaking from waves released when rock breaks or slips.

Focus (hypocenter): where the rock first slips. **Epicenter**: on the surface directly above. **Depth of focus**: between them.

Magnitude: energy at the source; one per earthquake. **Intensity**: shaking at a place.

Formulas

$d = v \times t$	1 km = 100,000 cm **Use:** plate motion, shortening
$\frac{\text{shortening}}{\text{original}} \times 100\%$	shortening = original − new **Use:** squeezed layer
$\frac{d}{3.5} - \frac{d}{6} = \text{gap}$	about 8.4 km per second of gap **Use:** distance of focus
10^d	d = difference in magnitude **Use:** wave height ratio
$\frac{E_1}{E_2} = 10^{1.5\,d}$	each step ≈ 32 times; 2 steps 1,000 **Use:** energy ratio

Why geology matters in Nepal

- **resources**
  - limestone
  - gems
  - sand
  - iron
  - groundwater
  - gravel
- **building safely**: roads, tunnels, dams, hydropower on broken rock
- **disasters**
  - landslides
  - glacial lake floods
  - earthquakes
  - fault, slope maps
- **the past**
  - old seas
  - ice ages
  - climate
- **farming, environment**: soil from rock; groundwater pollution

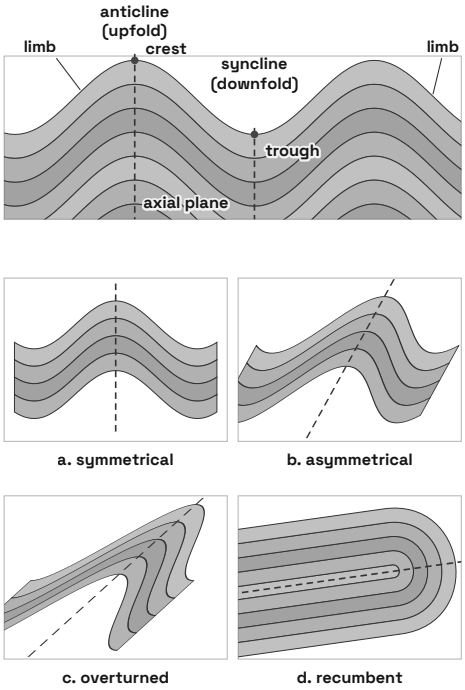
Tectonic plates

- large
  - Pacific
  - African
  - North American
  - Antarctic
  - South American
  - Indo-Australian
  - Eurasian
- continental crust: about 35 km (70 km under the Himalaya), light, like granite; oceanic: about 7 km, heavier, basalt
- move
  - mantle churning
  - **slab pull** (sinking sea floor)
  - **ridge push**
- 5 cm a year × 50 million years = 2,500 km

	Divergent	Convergent	Transform
Plates	apart	towards each other	past each other
Crust	made	destroyed (sinks) or piled up	neither
Landforms	mid-ocean ridges, rift valleys	trenches, volcanoes, fold mountains	faults offsetting rivers, roads
Earthquakes	shallow, small	largest	shallow, strong
Volcanoes	many	where sea floor sinks; few where continents collide	rare
Example	Mid-Atlantic Ridge, Iceland, East African Rift	Andes, Japan; Himalaya	San Andreas Fault

- Nepal: Terai and hills on the **Indian plate**, Tibet on the **Eurasian**; India north at 4–5 cm a year; about 2 cm a year across Nepal

Fold mountains



An anticline and a syncline, with crest, trough, limbs and axial plane; then (a) symmetrical, (b) asymmetrical, (c) overturned, (d) recumbent.

- rock bends (deep, hot, under pressure) instead of breaking
- **anticline**: upfold, slopes away from its middle; **crest**. **Syncline**: downfold; **trough**
- **limbs**: sloping sides; **axial plane**: divides the fold into halves
- symmetrical (upright, equal limbs) → asymmetrical (one steeper) → overturned (one limb past upright, older on top) → recumbent (on its side)

How the Himalaya formed:

1. **deposition**: mud, sand, shells on the floor of the **Tethys Sea**, about 200 million years ago; India part of Gondwana
2. **convergence**: India moves north; Tethys floor sinks under Asia
3. **collision**: about 50 million years ago; layers squeezed, folded, thrust, pushed up
4. **uplift and erosion**: still rising; worn down; sediment builds the plains

- sea fossils high up: shaligrams (ammonites) of the Kali Gandaki; Everest's top: limestone of a sea about 450 million years ago
- exam: **young fold mountains**; geologists now: thrust sheets, folded inside

Belt (S → N)	Main rocks	Some minerals and where
Terai	boulders, gravel, sand, silt, clay	sand, gravel; groundwater
Chure (Siwalik)	mudstone, siltstone, sandstone, conglomerate; soft, erodes	sand, gravel, building stone
Lesser Himalaya	shale, slate, phyllite, schist, quartzite, limestone, dolomite	limestone (Chobhar, Udayapur); slate (Bandipur); magnesite (Kharidhunga); iron, marble (Phulchoki, Godawari)
Higher Himalaya	gneiss, marble, granite	aquamarine, tourmaline (Taplejung, Sankhuwasabha)
Tethys Himalaya	fossil-rich limestone, shale, sandstone	ammonites (Kali Gandaki); gas seeps (Muktinath)

- thrusts S → N: **Main Frontal** (Terai | Chure), **Main Boundary** (Chure | Lesser), **Main Central** (Lesser | Higher)

Volcanoes

- **lava**: runny (poor in silica) flows far; sticky (rich in silica) piles near the vent
- **gases**
  - water vapor
  - CO_2
  - SO_2
- **active** (Kilauea, Etna)
- **dormant** (Fuji, 1707)
- **extinct** (Arthur's Seat)
- **shield**: broad, runny lava (Mauna Loa)
- **composite**: steep, layers of lava and ash, explosive (Fuji, Kilimanjaro)
- **cinder cone**: small, steep (Parícutin)
- **magma forms**
  - pressure drops (plates part)
  - water added (sinking plate)
  - extra heat (**hot spots**, Hawaii)
- magma lighter → rises → chamber; dissolved gas forms bubbles; pressure beats rock → eruption
- **Ring of Fire**: round the Pacific
- **Nepal: none**: continent meets continent, no wet plate sinks, no ridge or hot spot; hot springs (Tatopani) are water warmed deep along faults

Harmful:

- lava flows
- **pyroclastic flows** (deadliest; Pompeii, AD 79)
- ash falls
- lahars (Armero, 1985, about 23,000)
- gases, acid rain
- tsunamis (Krakatoa, 1883)

- cooling (Pinatubo 1991, about 0.5 °C; Tambora 1815)

Useful:

- fertile soil
- geothermal energy (Iceland)
- minerals, pumice, building stone
- new land

Reduce harm:

- watch (earthquake swarms, swelling, gas)
- hazard maps
- evacuation plans
- protect against ash
- divert lava

Earthquakes

- **elastic rebound** (Reid, after San Francisco 1906)
  - fault stuck by friction
  - rock bends, stores energy
  - force beats friction
  - slips, springs back
  - waves
- most foci under 70 km; Nepal's big ones 10–20 km down

Wave	Speed	Moves rock	Through
P (first)	about 6 km/s	push-pull, along its path	solids, liquids, gases
S (next)	about 3.5 km/s	side to side	solids only (outer core liquid)
surface (last)	slowest	rolls, sways	along the surface; most damage

- seismograph → seismogram; bigger P–S gap = farther; three stations locate it

	Magnitude	Intensity
Measures	energy at source	shaking at a place
Per earthquake	one value	differs by place
Scale	Richter, moment	Mercalli (I–XII)

- 7.8 against 7.3: waves 3.2 ×, energy 5.6 ×; 8.0 against 5.7: about 2,800 ×
- **causes**
  - tectonic (most)
  - volcanic
  - collapse
  - induced (reservoirs, mining, Koyna 1967)
- **Main Himalayan Thrust**
  - creeps below about 20 km, stuck above
  - 2 cm a year → 2 m a century
  - Himalaya pushed up
  - great earthquake every century or two

Earthquake	Magnitude	
1934 (2 Magh 1990 BS), eastern Nepal, Bihar	8.0	8,519 died in Nepal
1988, Udayapur	6.9	700+; building code followed
2015, Barpak, Gorkha	7.8	nearly 9,000; Dharahara fell
2015, Dolakha	7.3	largest aftershock
2023, Jajarkot	5.7	about 150 (near midnight)

- Gorkha broke only the deeper part
- shallow part still stores strain
- western Nepal: 500+ years, about 10 m stored

Effects:

- buildings fall: most deaths
- injuries
- homelessness
- disease
- heritage
- economy
- landslides (Langtang)
- dammed rivers
- cracks
- **liquefaction**
- tsunamis (2004)
- fires

Before:

- building code NBC 105 (1994; 2020)
- retrofit schools
- retrofit hospitals
- land use
- fix furniture
- emergency bag
- drills
- Safety Day, 2 Magh
- early warning (P waves)

During:

- indoors **Drop, Cover and Hold On**
- don't run out
- outdoors to open space
- in a vehicle stop away from bridges, slopes

After:

- expect aftershocks
- keep out of damaged buildings
- turn off gas
- listen to the radio

COMMON MISTAKES

✗ Magma and lava used for the same thing.
✓ Magma under the surface, lava on it.

✗ Epicenter is underground.
✓ The focus is; the epicenter is above it.

✗ Magnitude 8 is a bit more than 7.
✓ About 32 times the energy.

✗ Nepal's hot springs are volcanic.
✓ Water warmed deep along faults.

✗ Anticline is a downfold.
✓ Upfold; syncline is the downfold.

✗ Subtract the wave speeds.
✓ Subtract the travel times, $d/3.5 - d/6$.

✗ Run outside while shaking.
✓ Drop, Cover and Hold On.