

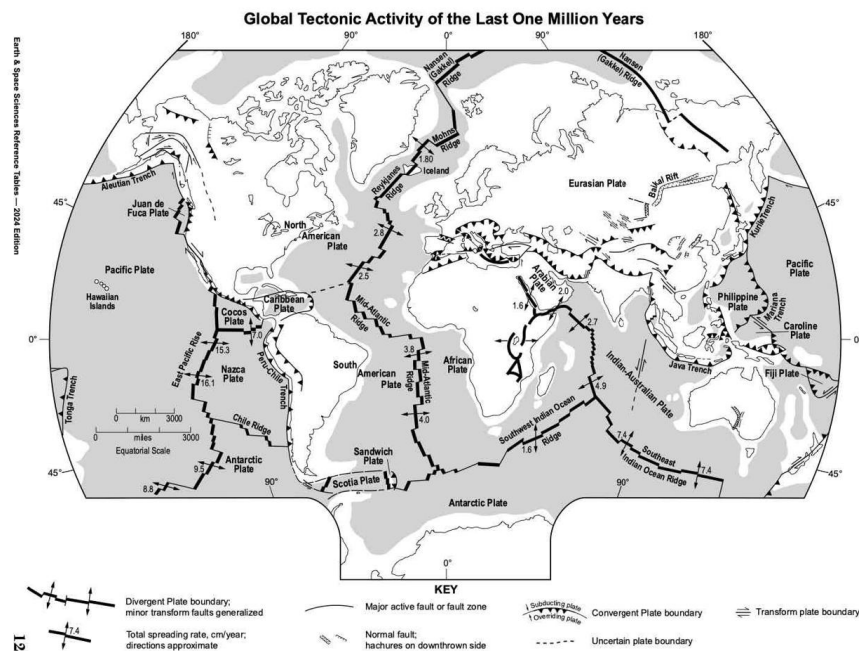
# Mr. Brown's Science Labs

Earth & Space Sciences | NYS Regents Review

## Plate Tectonics & Earthquakes

### Cluster Regents PDF Review

(With Rocks & Minerals connections throughout)



Name: \_\_\_\_\_ Period: \_\_\_\_\_

Date: \_\_\_\_\_ Score: \_\_\_\_\_ / 25

**Instructions:** This review contains **5 clusters** with **5 questions each** (25 total questions, 1 point each). Each cluster includes a brief reading passage and uses diagrams and data tables similar to those on the NYS Earth and Space Sciences Regents. Use your **Earth Science Reference Tables (ESRT)** when indicated. Show all work for calculation problems. After completing all questions, calculate your total score on the final page and use the print-to-PDF feature to save your answers.

# CLUSTER 1: EARTH'S INTERIOR STRUCTURE

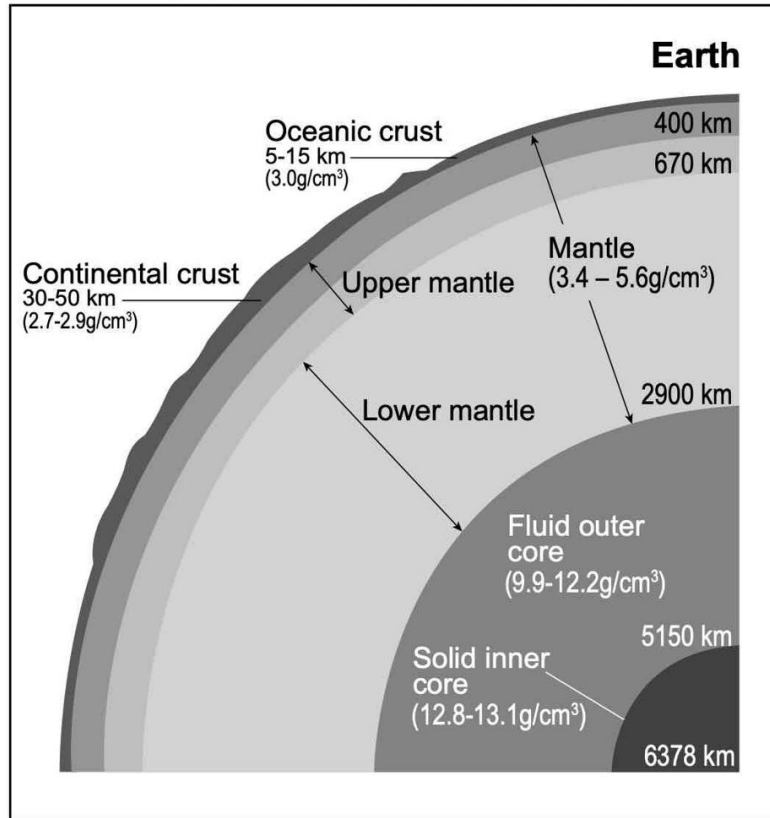
**Topics:** Earth's layers, density gradient, seismic wave behavior, core composition (*with sprinkled rocks & minerals*)

## ***Reading Passage: Mapping the Inside of Our Planet***

No human has ever traveled deeper than 12 kilometers into Earth's interior, yet geologists have constructed a detailed model of all 6,378 kilometers from the surface to the inner core. This was not done by drilling — it was done by listening. When earthquakes release energy, two main types of seismic waves race through Earth: **P-waves** (primary, compressional waves) and **S-waves** (secondary, shear waves). By recording how these waves bend, slow down, or stop entirely, scientists have inferred Earth's hidden structure.

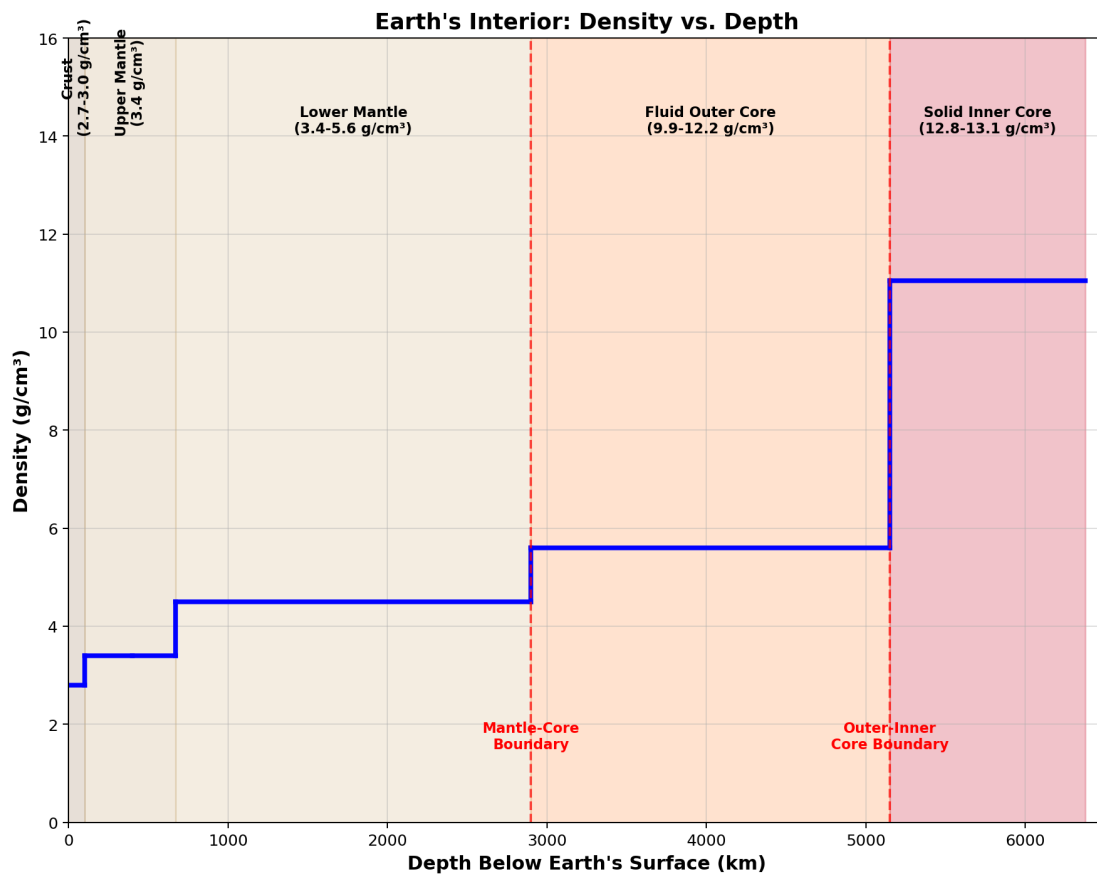
In 1906, geologist Andrija Mohorovicic noticed that seismic waves sped up suddenly at a depth of about 35 kilometers beneath continents — evidence of a boundary between the crust and the denser mantle. In 1914, Beno Gutenberg discovered that S-waves disappear entirely beyond a certain angle from any earthquake, leaving a "shadow zone" on the opposite side of the planet. Because S-waves cannot travel through liquids, this proved that part of Earth's core must be **fluid**. Later, the seismologist Inge Lehmann discovered that P-waves bend slightly inside the core, revealing a smaller **solid inner core** within the liquid outer core. Densities increase systematically with depth: the continental crust is just 2.7-2.9 g/cm<sup>3</sup>, while the inner core reaches 12.8-13.1 g/cm<sup>3</sup>. The continental crust is dominated by light, silica-rich igneous rocks like granite, while the upper mantle is composed of denser ultramafic rocks rich in olivine and pyroxene.

### Model of Earth's Interior Structure



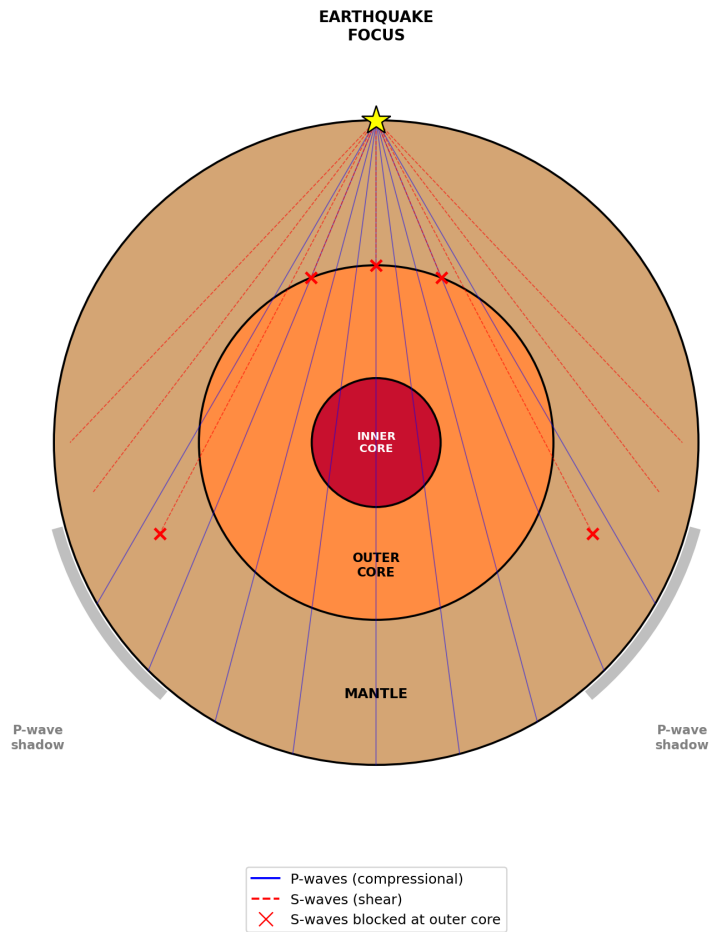
(Not drawn to scale)

**Figure 1.1:** ESRT page 11 — Model of Earth's Interior Structure. Note the layer thicknesses, density ranges, and the boundaries at 2,900 km (mantle/outer core) and 5,150 km (outer/inner core).



*Figure 1.2: Density vs. Depth profile graphed from ESRT page 11 data — useful for matching measured densities to specific layers.*

## Seismic Wave Behavior Through Earth's Interior



**Figure 1.3:** Seismic wave behavior. Note S-waves are blocked at the mantle-outer core boundary.

## Cluster 1 Questions (1 point each)

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1. A rock sample collected from deep within Earth has a measured density of  $4.8 \text{ g/cm}^3$ . Using Figure 1.1 (ESRT page 11) and Figure 1.2, this density is most consistent with which Earth layer?

- (1) Continental crust
- (2) Oceanic crust
- (3) Lower mantle
- (4) Solid inner core

2. Refer to Figure 1.3. The fact that S-waves are blocked at a depth of 2,900 km while P-waves pass through provides direct evidence that the layer between 2,900 km and 5,150 km is —

- (1) solid and very dense
- (2) liquid (fluid) iron and nickel
- (3) made of silica-rich granite
- (4) the same composition as the crust

3. Three students are studying Earth's interior. They each made a statement about how rocks and minerals relate to the layers:

**Student A:** "Continental crust is mostly composed of light, silica-rich rocks like granite."

**Student B:** "The upper mantle contains dense, dark minerals such as olivine and pyroxene."

**Student C:** "The fluid outer core is made of solid quartz and feldspar."

Which combination of students is correct?

- (1) Students A and B only
- (2) Students A and C only
- (3) Students B and C only
- (4) Students A, B, and C

4. The continental crust is composed primarily of granite, an igneous rock containing quartz, feldspar, and biotite mica. Compared to the basalt of the oceanic crust, granite has —

- (1) a higher density and darker color
- (2) a higher density and lighter color
- (3) a lower density and darker color
- (4) a lower density and lighter color

5. Earth's solid inner core has a temperature of about  $5,400^\circ\text{C}$  — hotter than the surface of the Sun — yet it remains solid. The best explanation for this is that —

- (1) the inner core has cooled below its melting point
- (2) the iron in the inner core is less dense than the outer core
- (3) extreme pressure forces iron atoms into a solid crystalline structure
- (4) radioactive decay is greatest in the outer core, not the inner core

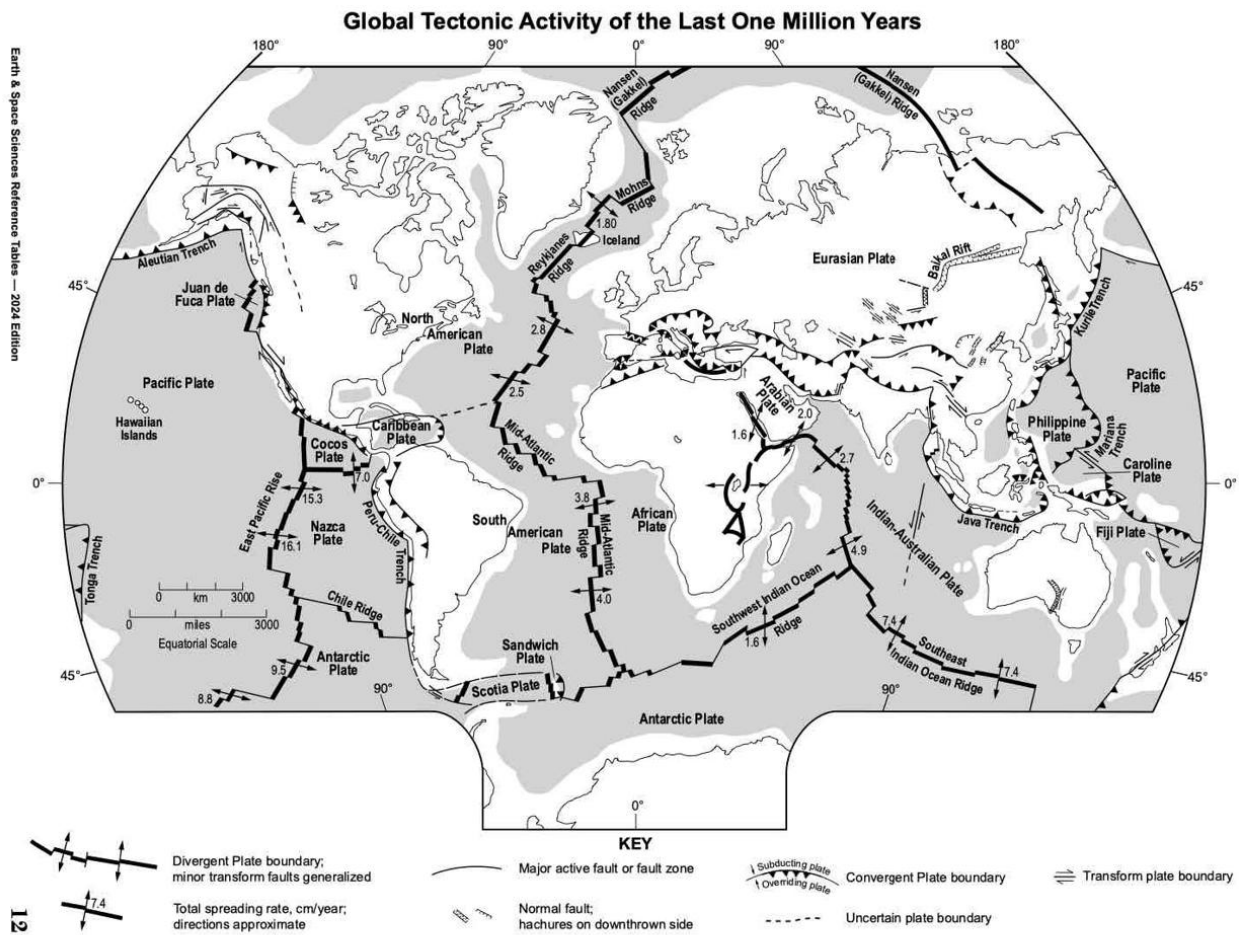
## CLUSTER 2: PLATE BOUNDARIES & TECTONIC MOVEMENT

**Topics:** Convergent, divergent, and transform boundaries; spreading rates; the Pacific Ring of Fire (*with sprinkled rocks & minerals*)

### ***Reading Passage: The Engine of Continental Motion***

Earth's lithosphere is broken into about a dozen large pieces called **tectonic plates** that are constantly moving — some at rates as slow as 2 cm per year, others as fast as 16 cm per year. The boundaries where these plates meet are the most geologically active places on the planet. At **convergent boundaries**, two plates push together; if one is denser oceanic crust, it dives beneath the other in a process called **subduction**, forming deep ocean trenches and chains of explosive volcanoes. The Pacific Ring of Fire is a horseshoe-shaped zone of subduction zones that produces about 90% of the world's earthquakes.

At **divergent boundaries**, plates pull apart and hot mantle material rises to fill the gap. This is how the Mid-Atlantic Ridge has been splitting Europe and Africa from the Americas for the past 180 million years. As magma cools at these ridges, it crystallizes into **basalt**, a fine-grained mafic igneous rock — the most common rock on Earth's surface. At **transform boundaries**, like the famous San Andreas Fault, plates slide past each other horizontally, producing frequent shallow earthquakes but no volcanism. The depth of earthquakes is a powerful clue: shallow quakes (less than 70 km) occur at all boundary types, but deep quakes (300-700 km) occur *only* at subduction zones, where the descending slab is dragged into the mantle. Around subduction zones, water released from the slab triggers melting that produces **andesitic** magma, which crystallizes into intermediate igneous rocks like andesite and diorite.



**Figure 2.1:** ESRT page 12 — Global Tectonic Activity of the Last One Million Years. Note the spreading rates (cm/year) along divergent boundaries, the convergent boundary trenches (Aleutian, Peru-Chile, Java, Mariana, etc.), and transform faults like the San Andreas.

## Cluster 2 Questions (1 point each)

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1. Using Figure 2.1 (ESRT page 12), locate the boundary between the Pacific Plate and the North American Plate that runs along the western coast of California (the San Andreas Fault). Earthquakes along this boundary are shallow, and the two plates slide horizontally past each other. This boundary is best classified as —

- (1) a convergent boundary with subduction
- (2) a divergent boundary forming new ocean crust
- (3) a transform boundary where plates slide past each other
- (4) a hotspot unrelated to plate boundaries

2. Using Figure 2.1 (ESRT page 12): the Mid-Atlantic Ridge has a total spreading rate of about 2.5 cm/year. How far apart would two points on opposite sides of the ridge be after 4 million years?

- (1) 10 km
- (2) 100 km
- (3) 1,000 km
- (4) 10,000 km

3. Using Figure 2.1 (ESRT page 12), examine the boundary between the Nazca Plate and the South American Plate (the Peru-Chile Trench, off the coast of Chile). Which row of the table below correctly identifies the boundary type, earthquake depth, and the type of igneous rock most commonly formed at this boundary?

Row	Boundary Type	Earthquake Depth	Common Igneous Rock
(1)	Divergent	Shallow only	Granite
(2)	Transform	Deep only	Basalt
(3)	Convergent (subduction)	Deep (250 km)	Andesite
(4)	Convergent (collision)	Shallow only	Marble

Which row contains the correct combination?

- (1) Row (1)
- (2) Row (2)
- (3) Row (3)
- (4) Row (4)

4. Three students made statements about the data shown in **Figure 2.1 (ESRT page 12)**:

**Student A:** "The East Pacific Rise spreads about six times faster than the Mid-Atlantic Ridge, so its ocean crust is much younger at the same distance from the ridge."

**Student B:** "Convergent boundaries with deep ocean trenches, such as the Peru-Chile Trench and the Java Trench, are subduction zones that can produce deep earthquakes."

**Student C:** "The Hawaiian Islands sit on a divergent plate boundary in the middle of the Pacific Plate, which is why they have active volcanoes."

Which combination of students is correct?

- (1) Students A and B only
- (2) Students A and C only
- (3) Students B and C only
- (4) Students A, B, and C

5. Using **Figure 2.1 (ESRT page 12)**: at the East Pacific Rise (a divergent boundary), upwelling mantle melts and produces magma. Which igneous rock would form as this magma cools rapidly underwater along the spreading center?

- (1) Granite, because divergent boundaries produce felsic magma
- (2) Basalt, because rapidly cooled mafic magma forms fine-grained rocks
- (3) Marble, because contact with seawater metamorphoses the magma
- (4) Sandstone, because sediments fill the rift zone

## CLUSTER 3: EARTHQUAKES & SEISMIC WAVES

**Topics:** P-wave / S-wave properties, travel-time graphs, epicenter triangulation, ground shaking (*with sprinkled rocks & minerals*)

### *Reading Passage: Reading Earth's Tremors*

When rocks deep underground suddenly slip past each other along a fault, the energy released radiates outward in all directions as seismic waves. The two main types — **P-waves** and **S-waves** — travel at different speeds and respond differently to the rocks they pass through. P-waves are **compressional**: they squeeze and stretch material in the same direction the wave is moving, like a slinky. They travel the fastest (about 6-13 km/s) and can pass through **solids, liquids, and gases**. S-waves are **shear** waves: they move material side-to-side, perpendicular to the direction of travel. They are slower (3-7 km/s) and cannot pass through liquids.

Because P-waves arrive at a seismograph station *before* S-waves, and because the time gap between them grows larger with distance, seismologists can use the **S-P interval** on a travel-time graph to calculate the distance from any station to the epicenter. With distances from **three or more** stations, geologists can locate the epicenter exactly using **triangulation**: draw a circle around each station with a radius equal to the calculated distance, and the epicenter is where all three circles intersect. The intensity of damage at the surface depends not only on magnitude and distance, but also on the bedrock beneath the site. Buildings on solid bedrock — such as Manhattan's Cambrian-Ordovician schist — experience less shaking than buildings built on **unconsolidated sediments** like the glacial sands of Long Island, which amplify seismic waves and increase damage.

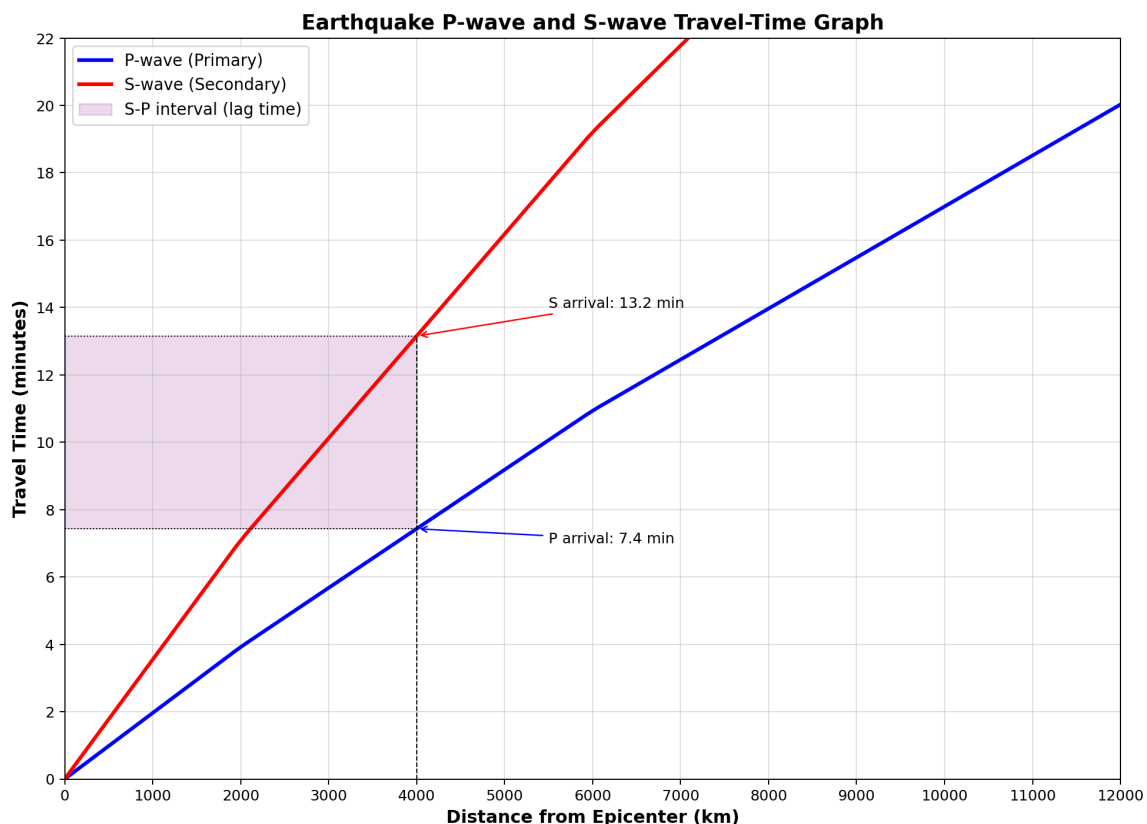


Figure 3.1: P-wave and S-wave travel-time graph (based on ESRT page 19).

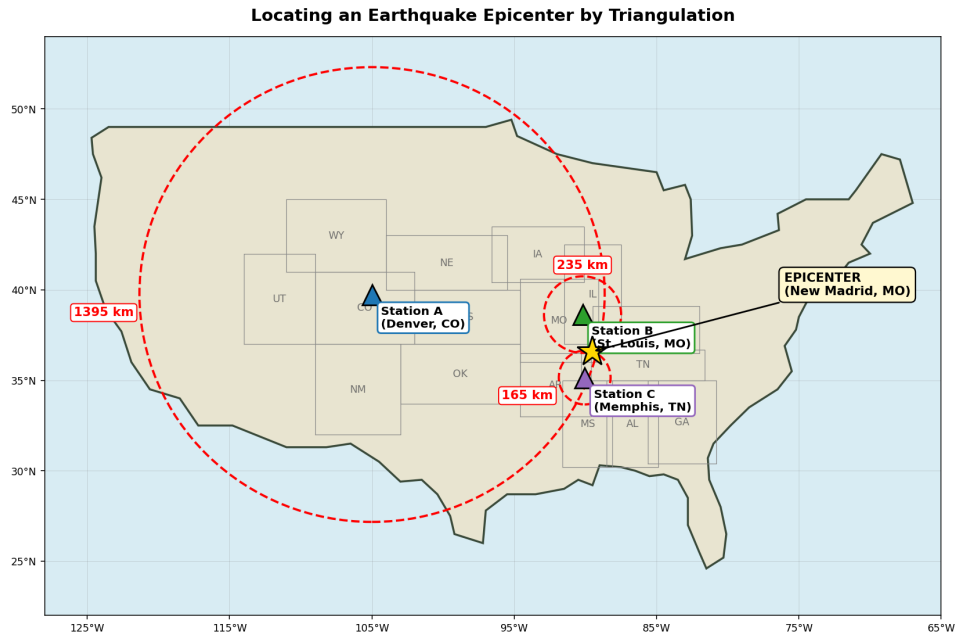


Figure 3.2: Triangulation of an earthquake epicenter from three seismic stations.

## Cluster 3 Questions (1 point each)

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1. Refer to Figure 3.1. At a seismograph station located 4,000 km from an earthquake epicenter, approximately how long would it take a P-wave to arrive after the earthquake occurred?

- (1) About 3 minutes
- (2) About 7 minutes
- (3) About 12 minutes
- (4) About 20 minutes

2. Using Figure 3.2, which statement best describes the location of the epicenter relative to the three seismic stations?

- (1) The epicenter is closest to Station C (Memphis), which recorded a 165 km distance.
- (2) The epicenter is closest to Station A (Denver), because Denver is farthest west.
- (3) The epicenter is exactly at Station B, because Station B is in the middle.
- (4) The epicenter cannot be located with only three stations.

3. An earthquake of equal magnitude shakes two locations in New York. Building X is constructed on solid Precambrian gneiss in the Adirondacks. Building Y is constructed on unconsolidated glacial sand on Long Island. Compared to Building X, Building Y will most likely experience —

- (1) less ground shaking, because sand is denser than gneiss
- (2) less ground shaking, because Long Island is closer to the epicenter
- (3) more ground shaking, because unconsolidated sediments amplify seismic waves
- (4) the same shaking, because earthquake magnitude is the only factor

4. Three students made claims about Figure 3.1:

**Student A:** "P-waves always arrive before S-waves at the same seismic station because P-waves travel faster."

**Student B:** "The S-P interval (gap between P and S arrivals) decreases as distance from the epicenter increases."

**Student C:** "If only one station records an earthquake, the exact epicenter location cannot be determined."

Which combination of students is correct?

- (1) Students A and B only
- (2) Students A and C only
- (3) Students B and C only
- (4) Students A, B, and C

**5. Refer to Figure 1.3 from Cluster 1 (seismic shadow zones). The existence of a P-wave shadow zone between approximately 105° and 140° from the epicenter is best explained by —**

- (1) P-waves being absorbed entirely by the inner core
- (2) P-waves being refracted (bent) as they enter the outer core
- (3) P-waves being unable to travel through any liquid
- (4) P-waves losing all their energy in the lower mantle

# CLUSTER 4: NYS MOUNTAIN BUILDING & GEOLOGY

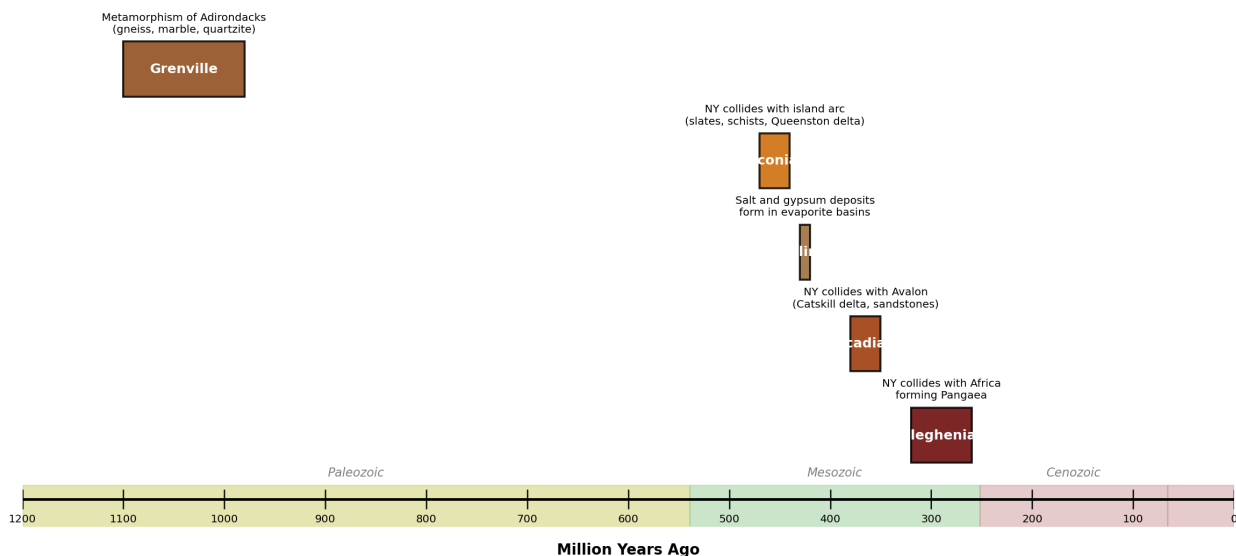
**Topics:** NYS orogenies (Grenville, Taconian, Acadian, Alleghenian), bedrock geology, geologic history (*with sprinkled rocks & minerals*)

## *Reading Passage: When Mountains Were Born in New York*

Although today New York State has rolling hills and broad lowlands rather than towering peaks, the bedrock beneath your feet records a violent history of **five major mountain-building events**, called **orogenies**. Each one was driven by plate tectonic collisions that formed mountains as tall as today's Himalayas. The oldest, the **Grenville orogeny** (~1.1 billion years ago), occurred during the Precambrian. It deeply metamorphosed rocks now exposed in the **Adirondack Mountains**, producing the gneiss, marble, and quartzite that hikers see today on Mt. Marcy. The Adirondacks themselves are not the original Grenville mountains — those eroded away long ago. They are a **dome-like uplift** that has only been rising for the past 20 million years.

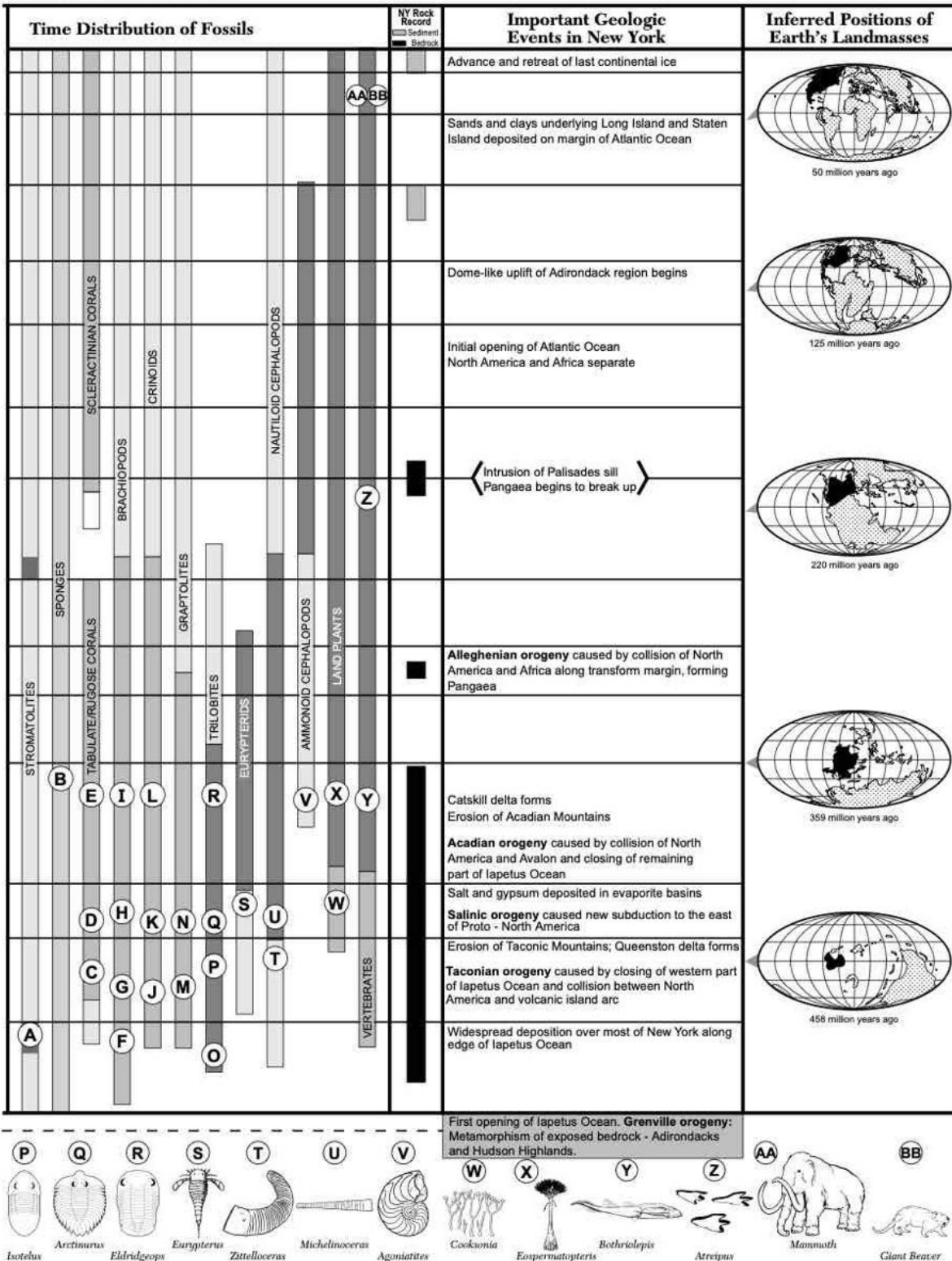
During the Paleozoic Era, three more orogenies shaped New York. The **Taconian orogeny** (470-440 mya, Ordovician) occurred when an island arc collided with the eastern edge of proto-North America, producing slates and the Queenston delta sediments. The **Acadian orogeny** (380-350 mya, Devonian) was caused by the collision of North America with the microcontinent **Avalon**; it produced the **Catskill delta** — a massive wedge of sandstone and shale that you can see today in the cliffs of the Catskill Mountains. The final Paleozoic event, the **Alleghenian orogeny** (320-260 mya), occurred when North America collided with Africa to form the supercontinent **Pangaea**. After Pangaea broke apart, the Atlantic Ocean opened, and during the Pleistocene Ice Age (the past 2.6 million years), advancing glaciers carved the Finger Lakes, formed Long Island's terminal moraines, and deposited the unconsolidated sands and gravels that make up the youngest rocks in NYS.

### Major Mountain-Building Events (Orogenies) Affecting New York State



**Figure 4.1:** Major mountain-building events (orogenies) in New York State, plotted on a geologic time scale.

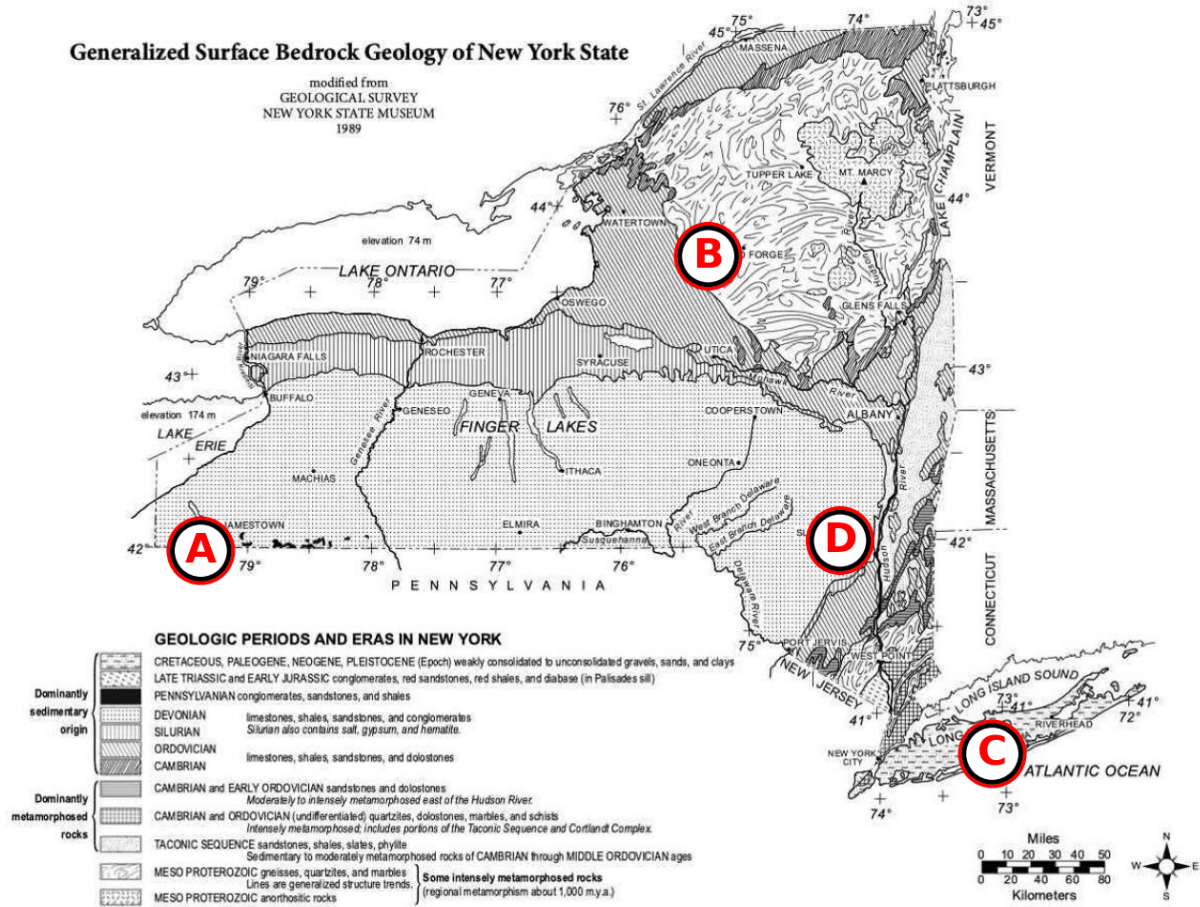
OF NEW YORK STATE



Earth & Space Sciences Reference Tables — 2024 Edition

Figure 4.2: ESRT page 7 — Geologic History of New York State. Key column: Important Geologic Events in New York (Grenville, Taconian, Salinic, Acadian, Alleghenian orogenies and the Pleistocene ice advance).

## Generalized Surface Bedrock Geology of New York State with Sample Locations A, B, C, D



**Figure 4.3:** Generalized Surface Bedrock Geology of New York State with sample locations A, B, C, and D marked. Use the legend at the bottom to identify the geologic period for each sample location.

## Cluster 4 Questions (1 point each)

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1. Refer to **Figure 4.3. Sample location B, located in the central Adirondacks near Old Forge, contains rocks formed during the —**

- (1) Grenville orogeny — Precambrian metamorphic gneiss and marble
- (2) Taconian orogeny — Ordovician slate and shale
- (3) Acadian orogeny — Devonian sandstone and conglomerate
- (4) Pleistocene glaciation — unconsolidated sand and gravel

2. Using **Figure 4.2 (ESRT page 7)** and **Figure 4.3**, which row correctly matches the sample location to the geologic period and to the rock type most likely found there?

Row	Location	Geologic Period	Rock Type
(1)	A	Devonian	Shale
(2)	B	Cambrian	Limestone
(3)	C	Pleistocene	Granite
(4)	D	Precambrian	Gneiss

Which row contains the correct combination?

- (1) Row (1)
- (2) Row (2)
- (3) Row (3)
- (4) Row (4)

3. The Grenville orogeny (~1.1 billion years ago) involved intense pressure and temperature, which transformed pre-existing sedimentary and igneous rocks of the Adirondack region into metamorphic rocks. Which group of rocks below is most characteristic of this metamorphism?

- (1) Sandstone, shale, and limestone
- (2) Basalt, andesite, and rhyolite
- (3) Gneiss, marble, and quartzite
- (4) Sand, silt, and clay

4. Three students made statements about NYS orogenies (refer to **Figure 4.1**):

**Student A:** "The Acadian orogeny was caused by the collision of North America with the microcontinent Avalon, producing the Catskill delta sandstones."

**Student B:** "The Alleghenian orogeny is the most recent orogeny that helped form the supercontinent Pangaea."

**Student C:** "The Taconian orogeny occurred during the Cretaceous Period of the Mesozoic Era."

Which combination of students is correct?

- (1) Students A and B only
- (2) Students A and C only
- (3) Students B and C only
- (4) Students A, B, and C

5. Using **Figure 4.1**, approximately how many millions of years passed between the start of the Taconian orogeny (470 mya) and the end of the Acadian orogeny (350 mya)?

- (1) About 80 million years
- (2) About 120 million years
- (3) About 200 million years
- (4) About 350 million years

## CLUSTER 5: VOLCANISM, IGNEOUS ROCKS & MINERAL RESOURCES

**Topics:** Volcanic processes, Bowen's reaction series, intrusive vs. extrusive igneous rocks, NYS mineral resources

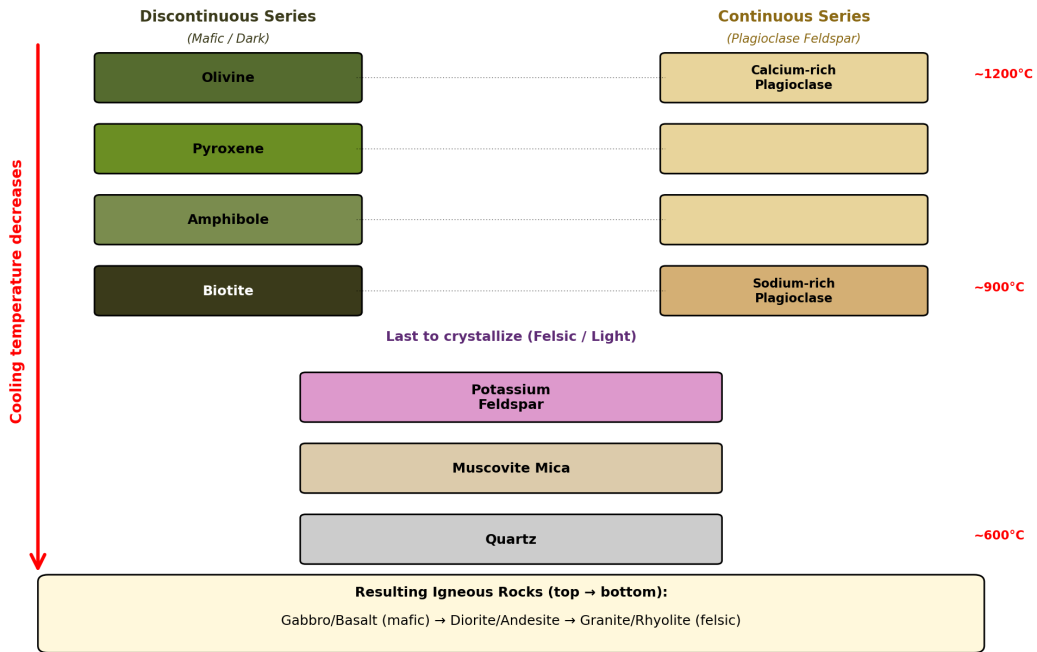
### *Reading Passage: Fire from Below*

Most of Earth's volcanic activity is concentrated along plate boundaries. At **convergent (subduction) boundaries**, water released from the descending oceanic plate triggers melting in the mantle wedge above, producing thick, gas-rich **andesitic magma** that often erupts explosively — the volcanoes of the Pacific Ring of Fire. At **divergent boundaries** and **hotspots** (like Hawaii), thinner **basaltic magma** erupts more gently as flowing lava. The minerals that crystallize from this magma are predicted by **Bowen's Reaction Series**: at high temperatures (~1200°C), **olivine** and **calcium-rich plagioclase** are first to crystallize. As the magma cools, it produces **pyroxene**, **amphibole**, **biotite mica**, and progressively more sodium-rich plagioclase. The lowest-temperature minerals (~600°C) — **potassium feldspar**, **muscovite mica**, and **quartz** — crystallize last.

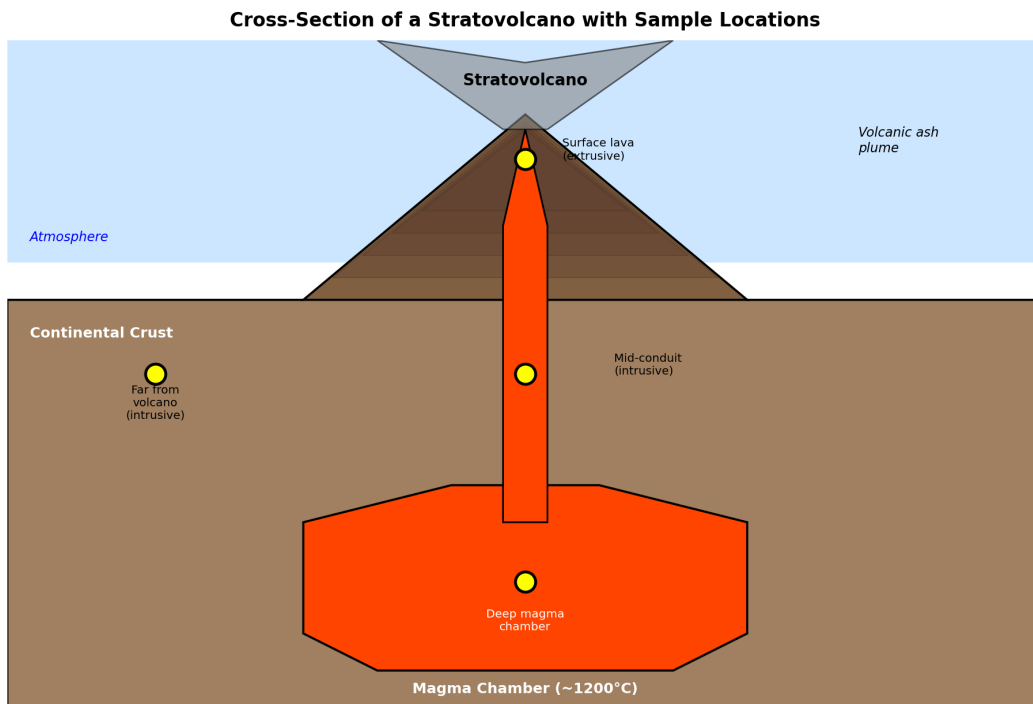
The grain size of an igneous rock reveals where it cooled. Magma that crystallizes slowly **deep underground** forms **intrusive** (plutonic) rocks like **granite** and **gabbro**, with large, visible crystals. Lava that erupts at the surface and cools quickly forms **extrusive** (volcanic) rocks like **basalt** and **rhyolite**, with tiny crystals or even glassy textures. Although New York State has no active volcanoes today, its rocks record ancient volcanic activity (such as the basalt of the Palisades sill, intruded during the breakup of Pangaea). New York is a major producer of non-volcanic mineral resources: **salt** and **gypsum** in central NY (deposited in evaporite basins during the Silurian), **peat** in the southern tier, and **garnet**, **talc**, and **wollastonite** mined from the metamorphic rocks of the Adirondacks.

## Bowen's Reaction Series

Order of mineral crystallization from cooling magma



**Figure 5.1:** Bowen's Reaction Series — order of mineral crystallization from cooling magma (high temp at top, low at bottom).



**Figure 5.2:** Stratovolcano cross-section with sample locations A-D at different depths and cooling environments.

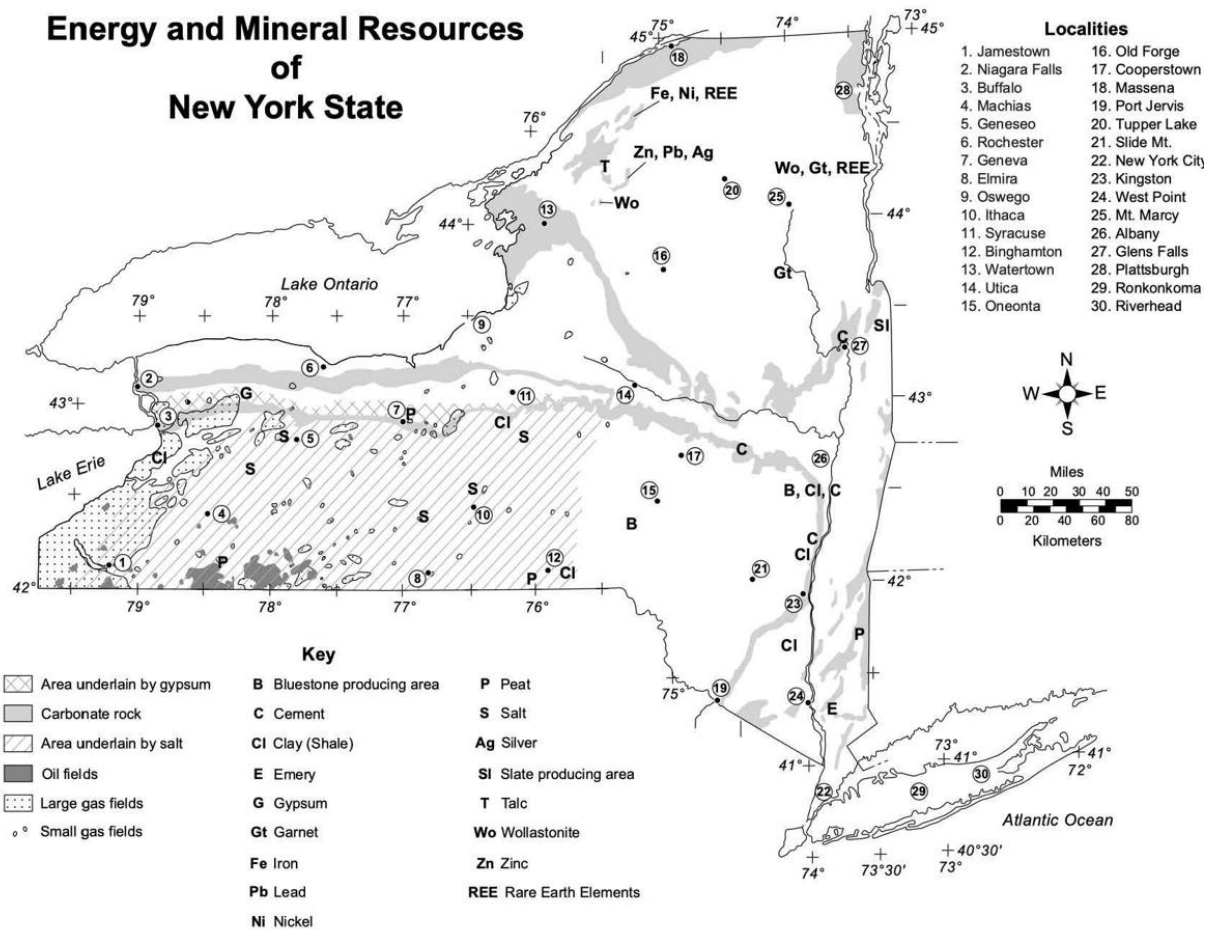


Figure 5.3: ESRT page 9 — Energy and Mineral Resources of New York State. Shows the locations of oil fields, gas fields, salt, gypsum, peat, and other mineral resources across the state.

## Cluster 5 Questions (1 point each)

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1. According to Bowen's Reaction Series (Figure 5.1), as a magma at 1200°C cools slowly to 600°C, which mineral would be the last to crystallize?

- (1) Olivine
- (2) Calcium-rich plagioclase
- (3) Biotite mica
- (4) Quartz

2. Refer to Figure 5.2. A geologist takes rock samples from points B (deep magma chamber, slow cooling) and D (surface lava flow, rapid cooling). The samples have the same composition. Compared to sample D, sample B will have —

- (1) smaller crystals, because deep cooling is faster
- (2) larger crystals, because slow cooling allows more crystal growth
- (3) no crystals at all, because magma never cools at depth
- (4) the same crystal size, because composition is the same

3. Using Figure 5.2 and your knowledge of igneous rocks, which row correctly identifies the sample location, cooling rate, and resulting rock type?

Row	Location	Cooling Rate	Resulting Rock
(1)	A	Slow (deep)	Granite (intrusive)
(2)	B	Fast (surface)	Basalt (extrusive)
(3)	C	Slow (deep)	Rhyolite (extrusive)
(4)	D	Slow (deep)	Gabbro (intrusive)

Which row contains the correct combination?

- (1) Row (1)
- (2) Row (2)
- (3) Row (3)
- (4) Row (4)

4. Using **Figure 5.3 (ESRT page 9)**, three students made statements about New York's mineral resources:

**Student A:** "Salt and gypsum deposits in central New York were formed in evaporite basins during the Silurian Period."

**Student B:** "The Adirondack Mountains are a major source of garnet, talc, and wollastonite — minerals associated with metamorphic rocks."

**Student C:** "New York's largest natural gas fields are located in the central Adirondacks, near Mt. Marcy."

Which combination of students is correct?

- (1) Students A and B only
- (2) Students A and C only
- (3) Students B and C only
- (4) Students A, B, and C

5. Using **Figure 5.3 (ESRT page 9)**, a student wants to study rock salt deposits. Which NYS city is located in an area underlain by salt?

- (1) Plattsburgh
- (2) Old Forge
- (3) Ithaca
- (4) Riverhead

# Final Grade Report

Cluster	Topic	Score
Cluster 1	Earth's Interior Structure	____ / 5
Cluster 2	Plate Boundaries & Tectonic Movement	____ / 5
Cluster 3	Earthquakes & Seismic Waves	____ / 5
Cluster 4	NYS Mountain Building & Geology	____ / 5
Cluster 5	Volcanism, Igneous Rocks & Mineral Resources	____ / 5
<b>TOTAL</b>		<b>____ / 25</b>

## Letter Grade Scale (out of 25 points):

Score	Percent	Letter Grade	Regents Performance Level
23-25	92-100%	A	Mastery (Level 5)
20-22	80-88%	B	Proficient (Level 4)
16-19	64-76%	C	Approaching (Level 3)
13-15	52-60%	D	Developing (Level 2)
0-12	0-48%	F	Below Standard (Level 1)

### ★ Save Your Work ★

Use your browser or computer's Print to PDF feature to save a copy of this completed review with your answers, scores, and final grade. Submit the saved PDF to your teacher or save it for your own study reference. Data tables, graphs, questions, and your written responses will all be preserved in the printed PDF.

**Self-Reflection: Which cluster was most challenging? What concepts do you need to review further?**

# Answer Key (Teacher Reference)

Detach or hide this page before distributing to students.

Cluster	Q#	Answer	Brief Explanation
1	1	(3) Lower mantle	4.8 g/cm <sup>3</sup> falls in the lower mantle range (3.4-5.6) — closer to lower mantle.
1	2	(2) liquid (fluid) iron and nickel	S-waves cannot travel through liquid; the outer core blocks them.
1	3	(1) Students A and B only	Outer core is iron-nickel alloy, NOT quartz/feldspar. Student C is wrong.
1	4	(4) lower density and lighter color	Granite (continental, 2.7 g/cm <sup>3</sup> ) is less dense and lighter than basalt.
1	5	(3) extreme pressure forces iron atoms into a solid crystalline structure	Pressure (not temperature) keeps the inner core solid.
2	1	(3) a transform boundary	San Andreas Fault = Pacific/N. American plates sliding past each other = transform.
2	2	(2) 100 km	2.5 cm/yr × 4,000,000 yr = 10,000,000 cm = 100 km.
2	3	(3) Row (3): Convergent (subduction), Deep (250 km), Andesite	Peru-Chile Trench: Nazca subducts under S. America → deep quakes + andesite.
2	4	(1) Students A and B only	Hawaii is a hotspot, NOT a divergent boundary. Statement C is wrong.
2	5	(2) Basalt - rapidly cooled mafic magma forms fine-grained rocks	Mid-ocean ridges produce basalt, not granite.
3	1	(2) About 7 minutes	From travel-time graph: 4,000 km → ~7 min for P-wave.
3	2	(1) The epicenter is closest to Station C (Memphis)	Smallest distance (165 km) means epicenter is nearest to Memphis.
3	3	(3) more ground shaking - unconsolidated sediments amplify	Loose sediments amplify seismic waves; bedrock dampens them.
3	4	(2) Students A and C only	Student B is wrong: S-P interval INCREASES with distance, not decreases.
3	5	(2) P-waves being refracted (bent) as they enter the outer core	The shadow zone is created by refraction at the mantle-core boundary.
4	1	(1) Grenville orogeny - Precambrian gneiss/marble	Adirondacks = Precambrian metamorphic rocks from Grenville.
4	2	(1) Row (1): A, Devonian, Shale	Location A is Allegheny Plateau = Devonian shale.
4	3	(3) Gneiss, marble, and quartzite	These are the classic Adirondack metamorphic rocks.
4	4	(1) Students A and B only	Taconian was Ordovician (Paleozoic), NOT Cretaceous (Mesozoic).
4	5	(2) About 120 million years	470 - 350 = 120 million years.
5	1	(4) Quartz	Quartz is the LAST mineral to crystallize at the lowest temperature.
5	2	(2) larger crystals - slow cooling allows more crystal growth	Slow cooling = bigger crystals (intrusive); fast cooling = small (extrusive).
5	3	(1) Row (1): A, Slow (deep), Granite (intrusive)	Point A is intrusive (deep, slow cooling) → granite. Other rows mismatch location & cooling.

5	4	(1) Students A and B only	Student C is wrong: NY gas fields are in southwestern NY, not Adirondacks.
5	5	(3) Ithaca	On ESRT page 9, Ithaca is in the area underlain by salt.

### Question Style Reference (Mimicking June 2025 Regents):

Regents #	Question Style	Cluster Examples
Q2	Standard MC about earth properties	1.1, 1.5
Q3	ESRT-based identification	1.1, 2.5, 3.3, 5.2
Q5	MC with diagram interpretation	1.2, 3.5
Q9	Plate tectonics/location MC	2.1, 4.1, 5.5
Q10	Calculation from data/map	2.2, 4.5
Q19	Three-statement combination MC	1.3, 2.4, 3.4, 4.4, 5.4
Q20	Travel-time graph reading	3.1
Q21	Standard mineral/igneous MC	1.4, 4.3, 5.1
Q23	Evidence-based row table	2.3, 4.2, 5.3

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