Name:

***Real World Globes:* Intro to Earth Seismicity and Earthquakes**

Objective: Promote an understanding of Earth's seismicity through observation, interpretation, and open discussion.

Materials Needed:
18" or 10" Real World Globe
RWG Earth Seismicity self-adhesive globe overlays applied to globe
Dry Erase marker
Earth Interior work board
Colored pencils, crayons, or markers (purple, blue, green, yellow)

INTRODUCTION

Earthquakes are widespread and very common phenomenon on Earth. Typically, only the destructive ones make the news, so many of us are unaware of just how prevalent they are. In fact, on average, approximately 20,000 earthquakes are located and recorded each year (that's roughly 55 earthquakes per day) (*USGS*), but many of these are too small to feel. So why are earthquakes so common? What causes them? Where do they occur? This activity is designed to answer these questions and more.

Read through the following definitions, you'll need them to complete some of the questions in the activities.

Seismicity: the worldwide or local distribution of earthquakes in space, time, and magnitude.

Focus: the point within the earth where an earthquake rupture starts (figure 1).

Epicenter: the point on the Earth's surface directly above the focus (figure 1).

Magnitude: a number (prefixed by 'Mw' of 'M'): that characterizes the relative size of an earthquake. It is representative of the amount of energy released by an earthquake. Each whole number increase represents a 32-fold increase in energy.

Plate tectonics is the large-scale movement of Earth's crust, and results in a number of distinct **tectonic settings**: convergent, divergent, strike-slip (figure 2).

Cross Section: A cutaway view of the Earth's interior (figure 1).

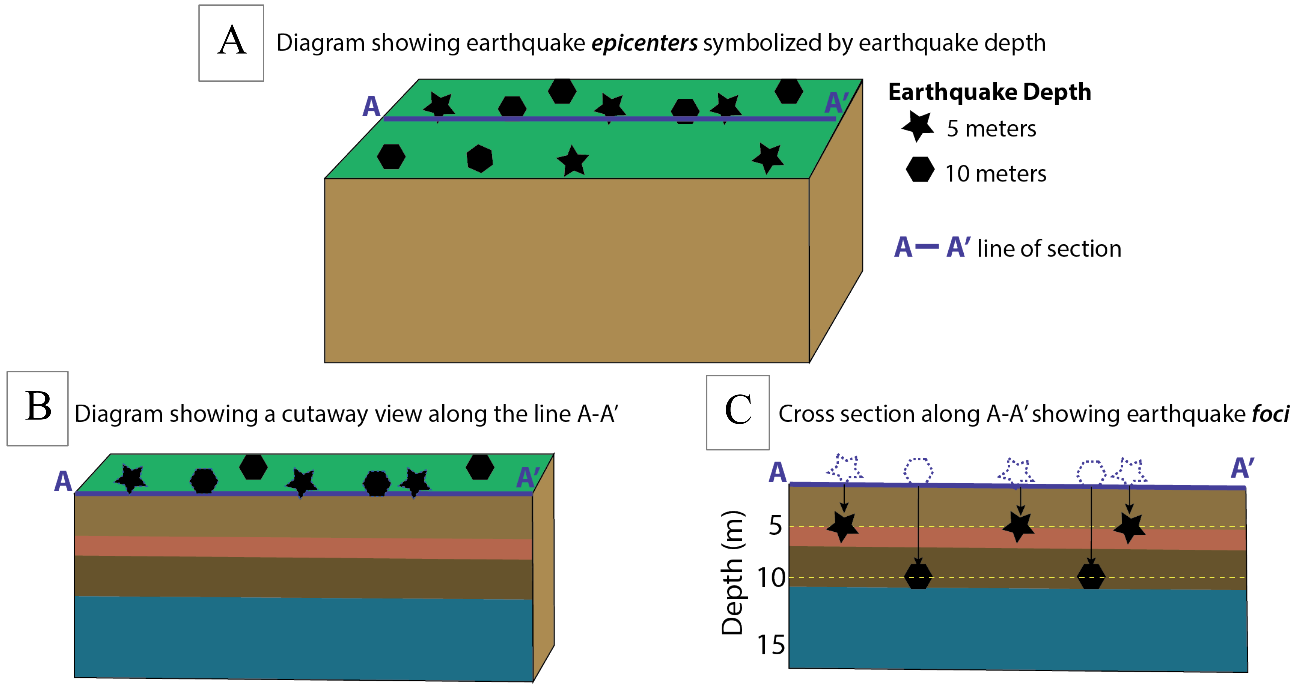


Figure 1. *Diagrams (completely fictitious) depicting **(A)** earthquake locations projected to the surface of the Earth (earthquake epicenters). The earthquakes did not originate at the surface, they originated at depth, and the different symbols inform you at what depth they originated. **(B)** A cutaway view of Earth's interior – imagine taking a knife to diagram A and slicing along the A-A' line, then removing the front piece – this is the what you would see. Earthquake epicenters are still shown. **(C)** A cross-section along the A-A' line. Now all we see is the newly revealed 'cut-face' along the A-A' line. Earthquakes are now depicted where they originated, at depth (their foci).*

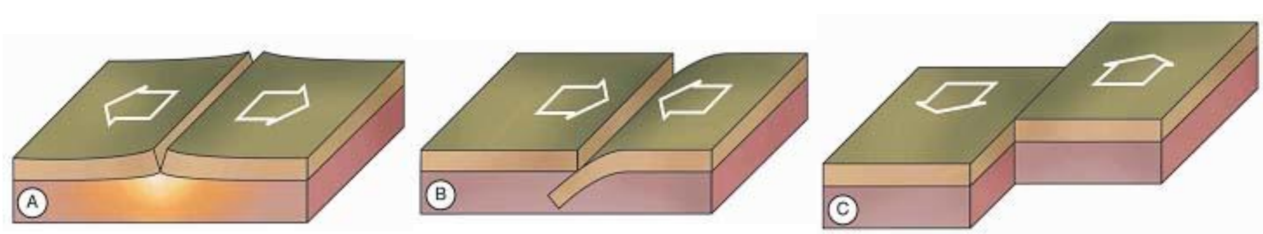


Figure 2. *Tectonic settings. **(A)** Divergent boundary, pieces of Earth's crust move away from each other. **(B)** Convergent boundary, pieces of Earth's crust collide with each other. This sometimes results in one side diving below the other (subduction zone). **(C)** strike-slip boundary, pieces of Earth's crust slide past each other.*

ACTIVITIES

Activity 1 – Observations and Interpretations:

Instructions:
Using the 3D *Real World Globe* and *Global Seismicity Kit*, answer the following questions.

1. What do the dots represent?
2. What do the different colors represent? (Hint: look for Africa)
3. What do the different dot sizes represent?
4. Are the dots randomly located across the globe? If no, what pattern(s) do you observe about their locations?
5. Are the different colors randomly located across the globe? If no, what pattern(s) do you observe?
6. Using a black dry-erase marker, draw lines to "connect the dots" around the globe as best you can. What do you think the lines you just drew represent?
7. Were you able to connect all the dots approximately seamlessly, or do some dots not quite follow your lines?

8. Interpret: where to earthquakes occur? Make sure to use observations to back up your interpretations.

9. Hypothesize: why do earthquakes occur? Use your interpretation(s) in question 9 to answer this question as best you can. (There are no wrong answers here).

Activity 2 – Cross Sections (the third dimension):

Instructions:
Use the cross sections provided on pages 8-11 to look at where earthquakes initiate beneath the Earth's surface. The earthquake location at depth is called the *Focus*, it's corresponding location on land is the *Epicenter*. For each cross section, **FIRST** use the line of section (A-A'), the plotted earthquakes in figure A, and the pie chart in figure C to **mark the locations/depth ranges of earthquakes in the cross section at the bottom of the page** in figure D. Be sure to use colors that correspond to the dots in figure A.

Once you are done, have them reviewed by your instructor, they will provide you with what you'll need to answer the following questions.

Cross Section 1: Atlantic Ocean

10. What is the range of depths at which earthquakes occur here?

11. At what depth do the majority of the earthquakes occur?

12. What type of tectonic setting are you looking at here?

13. Look at the globe, find where this cross section is located, then find at least two similar regions to the one depicted in this cross section. Briefly describe their locations. Do the earthquakes in your two other regions have a similar depth range? Similar size range? or different?

14. What generates earthquakes in this tectonic setting?

Cross Section 2: Central California

15. What is the range of depths at which earthquakes occur here?

16. At what depth do the majority of the earthquakes occur?

17. What type of tectonic setting are you looking at here?

18. What generates earthquakes in this tectonic setting?

Cross Section 3: South-Central Chile

19. What is the range of depths at which earthquakes occur here?

20. At what depth do the majority of the earthquakes occur?

21. What type of tectonic setting are you looking at here?

22. Look at the globe, find where this cross section is located, then find at least two similar regions to the one depicted in this cross section. Do the earthquakes in your two other regions have a similar depth range? Similar size range? or different?

23. What generates earthquakes in this tectonic setting?

Cross Section 4: Eastern Nepal

24. What is the range of depths at which earthquakes occur here?

25. At what depth do the majority of the earthquakes occur?

26. What type of tectonic setting are you looking at here?

27. What generates earthquakes in this tectonic setting?

Activity 3 – Synthesis:

Take a guess:

28. At what depth did the deepest earthquake ever to be recorded occur?

29. Where did the deadliest earthquake occur?

30. What's the largest magnitude earthquake ever to be recorded?

Do your best to answer these questions. We'll discuss them later as a class.

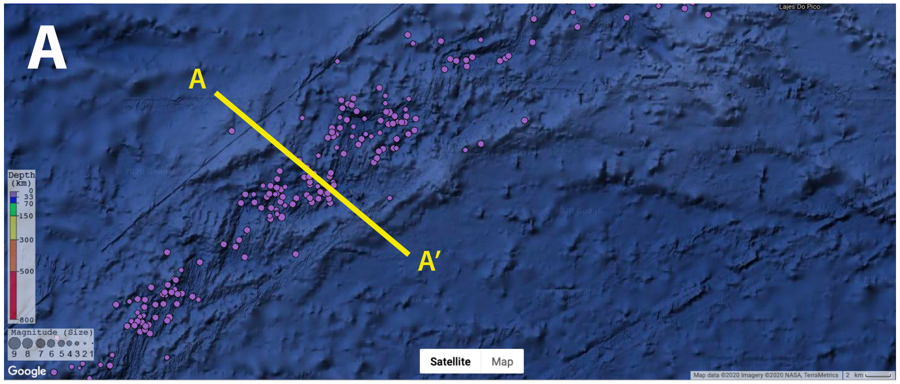
31. Where, specifically, do earthquakes occur (hint: it's a planar surface)

32. How and why do earthquakes occur

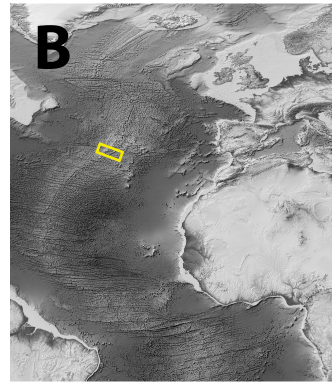
33. Why don't some earthquakes shown on the globe fall on the discrete lines you drew in Activity 1?

Notes from class discussion:

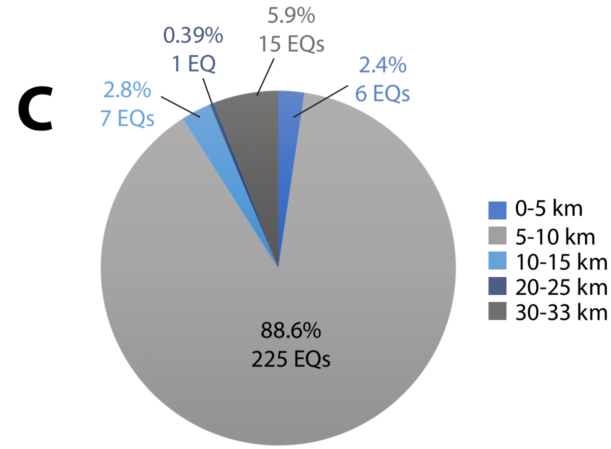
Cross Section 1: Atlantic Ocean



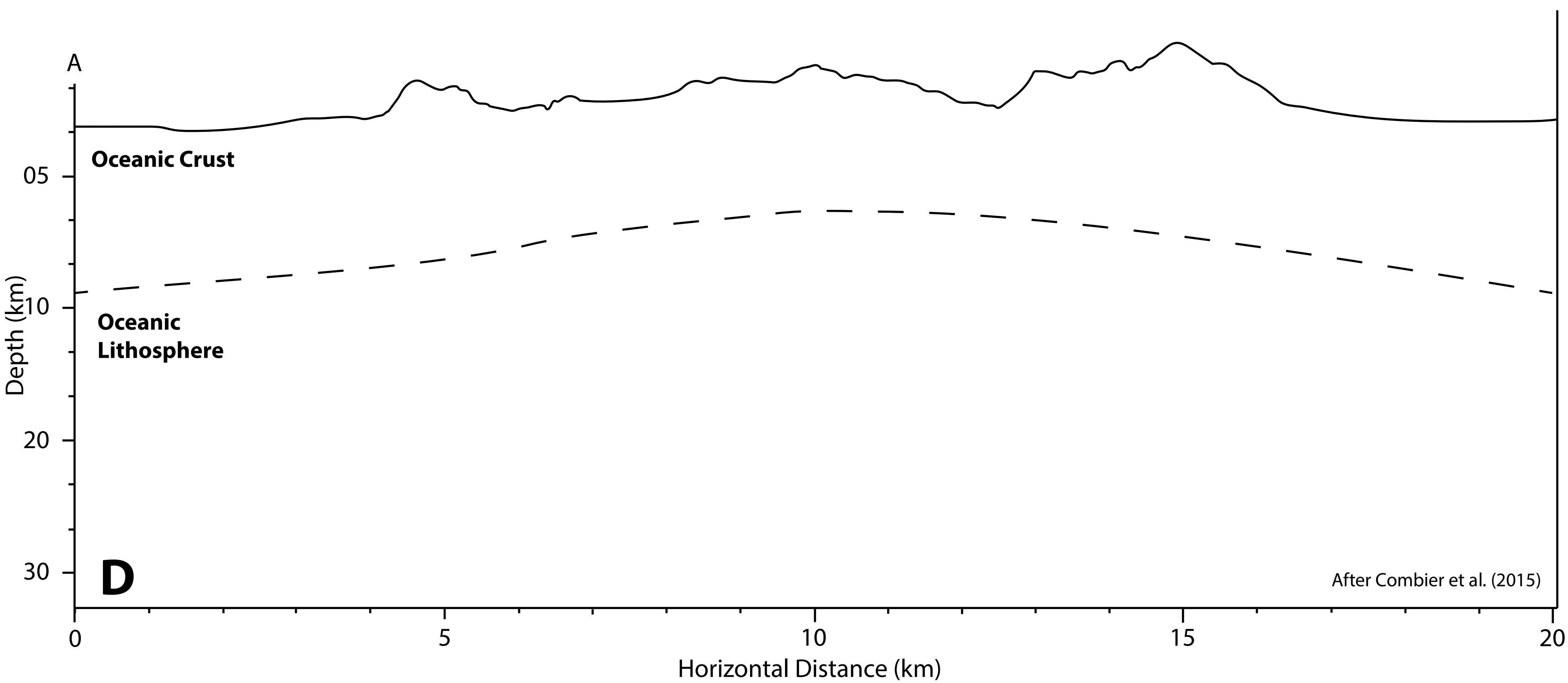
(**A**) Bathymetry and earthquake epicenters, Jan. 1964 - Jan. 2020, magnitude 3+. Data and imagery from IRIS Earthquake Browser.



(**B**) Map of figure A location. Image from NOAA (doi:10.7289/V5C8276).

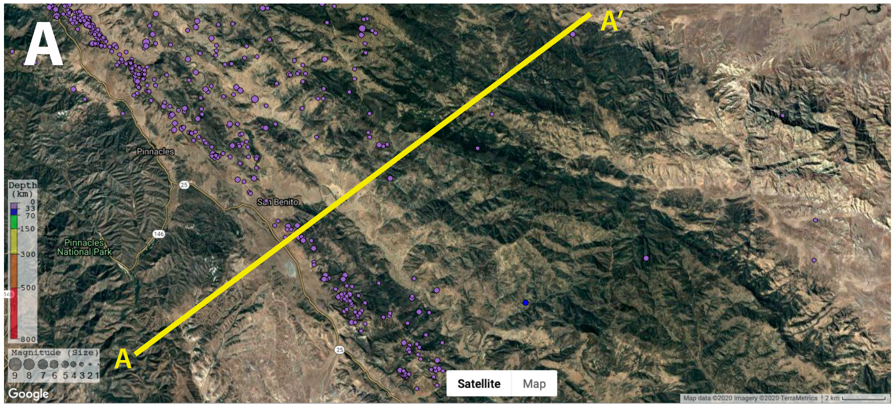


(**C**) A more detailed look at depth versus number of earthquakes shown in figure A.

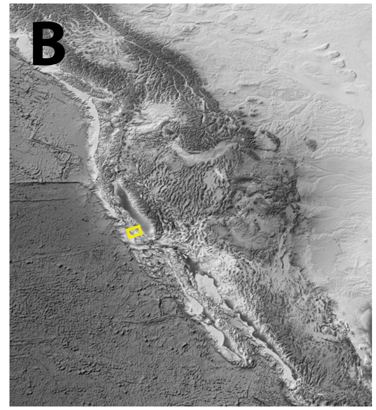


(**D**) Cross section (or depth profile) along A-A′ in figure A.

Cross Section 2: Central California



(**A**) Terrain and earthquake epicenters, Jan. 1964 - Jan. 2020, magnitude 3+. Data and imagery from IRIS Earthquake Browser.



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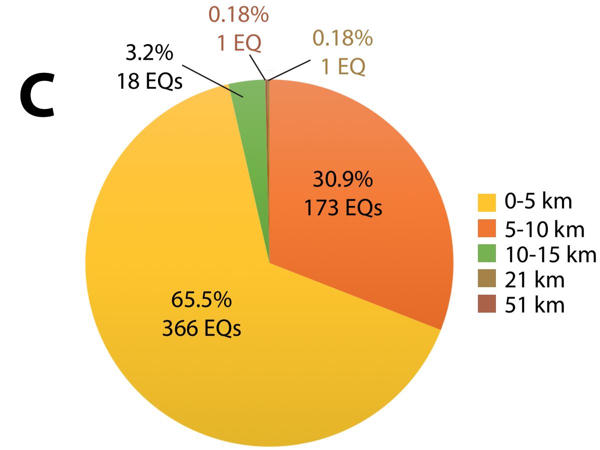

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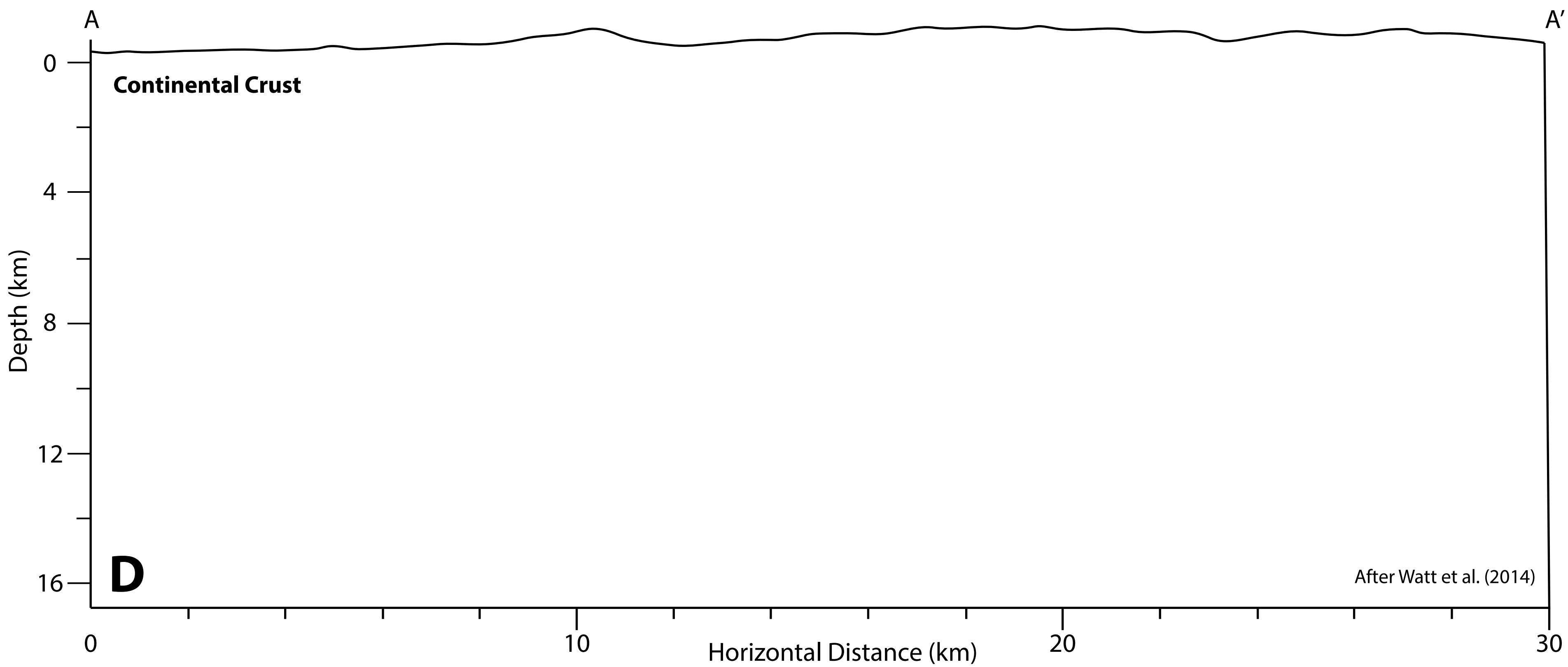

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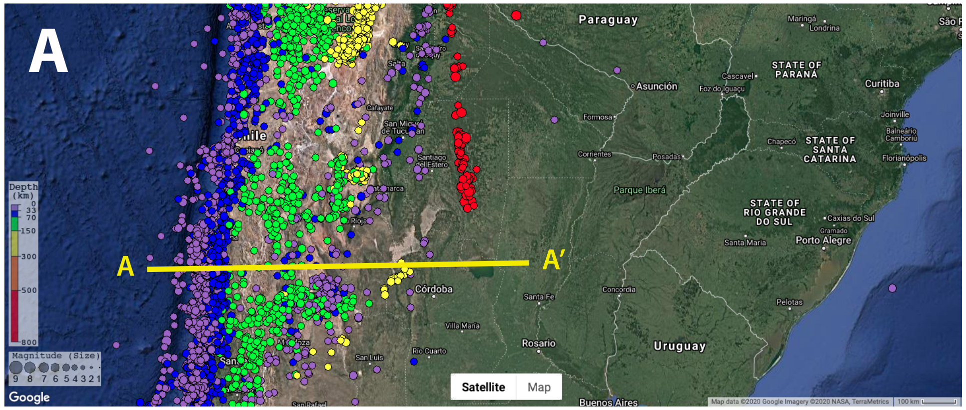
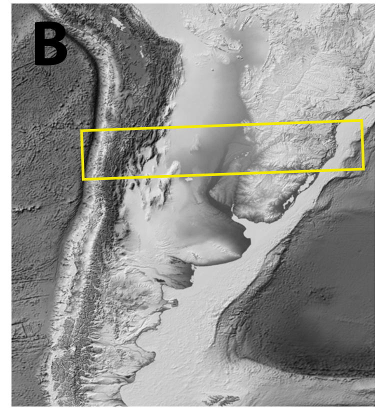
Cross Section 3: South-Central Chile



(**A**) Terrain, bathymetry, and earthquake epicenters, Jan. 1964 - Jan. 2020, magnitude 3+ (5000 of 30,293 shown). Data and imagery from IRIS Earthquake Browser.



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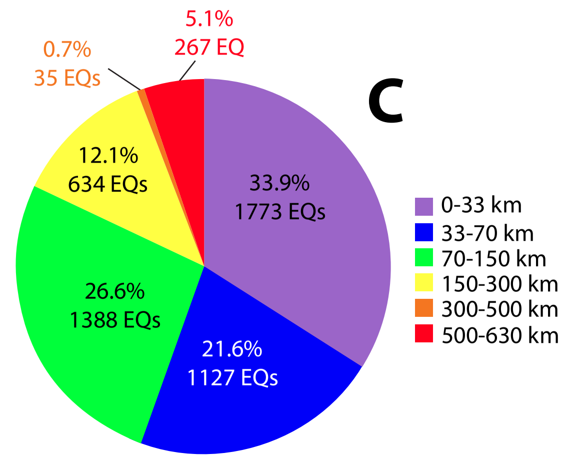

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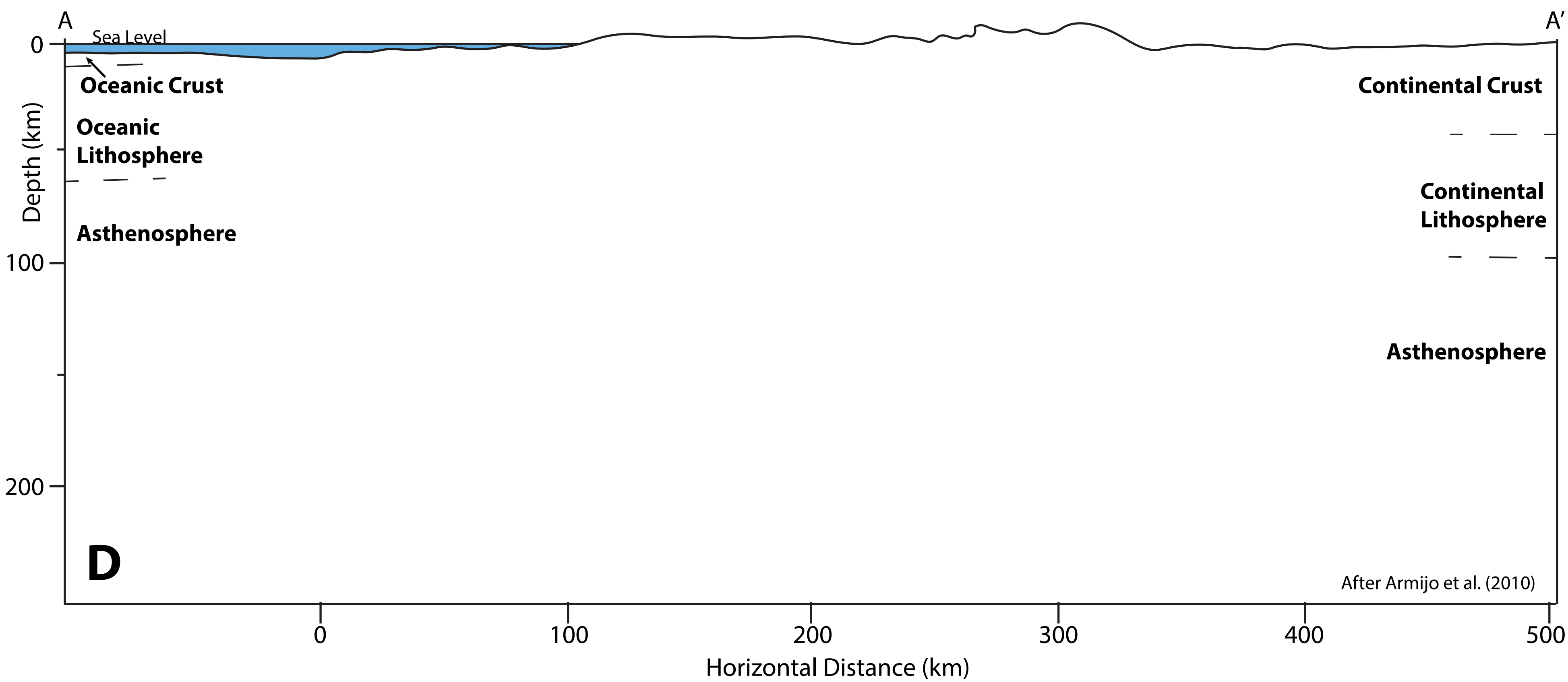

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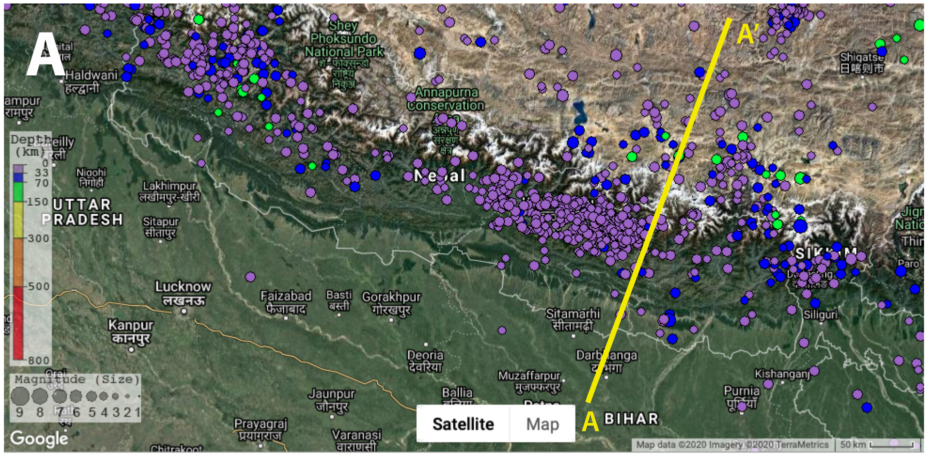
Cross Section 4: Eastern Nepal



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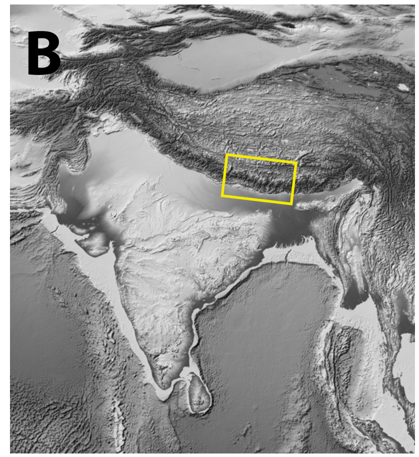

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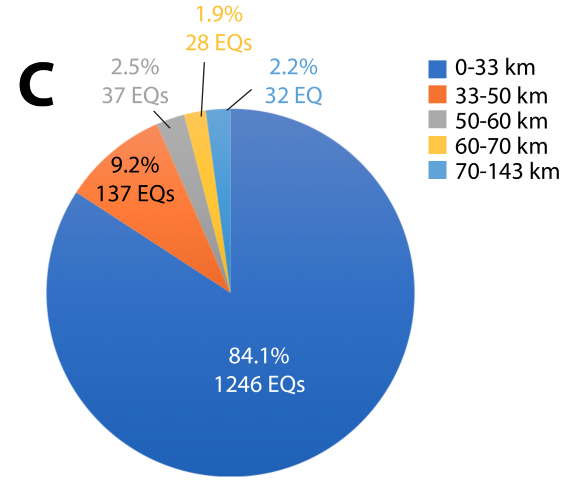

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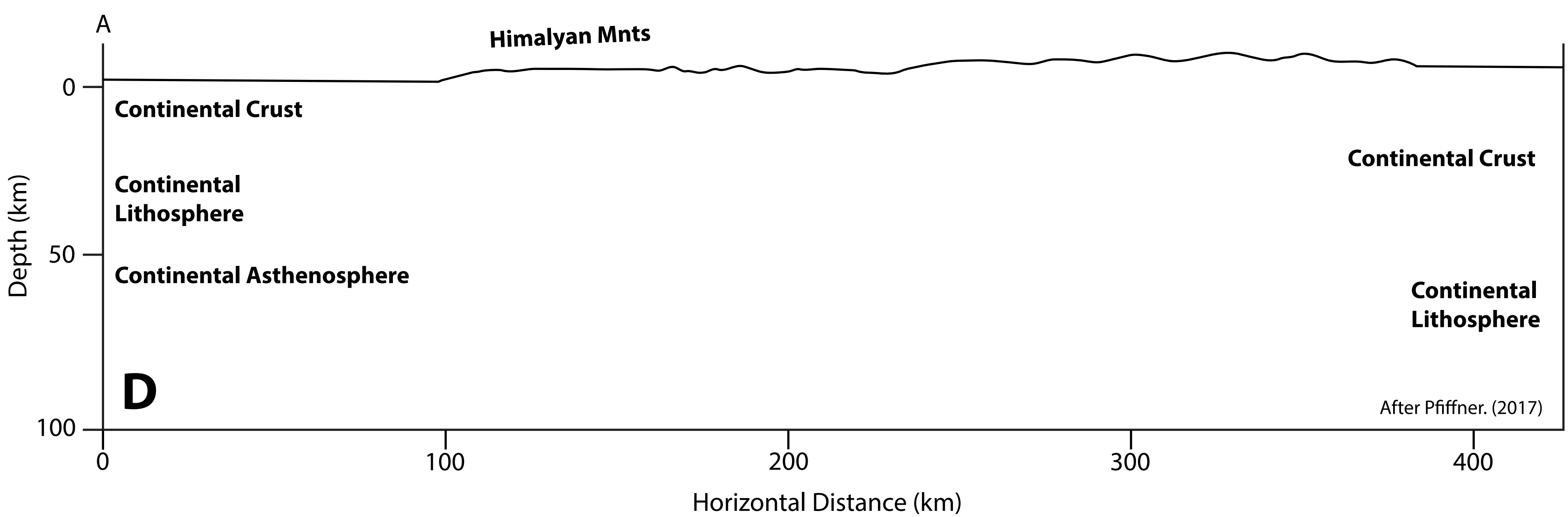

(**D**) Cross section (or depth profile) along A-A' shown in figure A.

Students who demonstrate understanding can:

HS-ESS2-1. Develop a model to illustrate how Earth's internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).] [Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.]

HS-ESS2-2. Analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth's systems. [Clarification Statement: Examples should include climate feedbacks, such as how an increase in greenhouse gases causes a rise in global temperatures that melts glacial ice, which reduces the amount of sunlight reflected from Earth's surface, increasing surface temperatures and further reducing the amount of ice. Examples could also be taken from other system interactions, such as how the loss of ground vegetation causes an increase in water runoff and soil erosion; how dammed rivers increase groundwater recharge, decrease sediment transport, and increase coastal erosion; or how the loss of wetlands causes a decrease in local humidity that further reduces the wetland extent.]

HS-ESS2-3. Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection. [Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.]

HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. [Clarification Statement: Examples of the causes of climate change differ by timescale, over 1-10 years: large volcanic eruption, ocean circulation; 10-100s of years: changes in human activity, ocean circulation, solar output; 10-100s of thousands of years: changes to Earth's orbit and the orientation of its axis; and 10-100s of millions of years:

*The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.
**California clarification statements, marked with double asterisks, were incorporated by the California Science Expert Review Panel

The star symbol (★) following the standard indicates that it is also a Modeling standard. Modeling is best interpreted not as a collection of isolated topics but in relation to other standards. Making mathematical models is a Standard for Mathematical Practice, and modeling standards appear throughout the higher mathematics standards indicated by a ★ symbol.

The section entitled "Disciplinary Core Ideas" is reproduced verbatim from *A Framework for K–12 Science Education: Practices, Cross-Cutting Concepts, and Core Ideas*.

Grades Nine through Twelve
Standards Arranged by Disciplinary Core Ideas

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s). ▪ Develop a model based on evidence to illustrate the relationships between systems or between components of a system. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-6) ▪ Use a model to provide mechanistic accounts of phenomena. (HS-ESS2-4) **Planning and Carrying Out Investigations** Planning and carrying out investigations in 9–12 builds on K–8 experiences and progresses to include investigations that provide evidence for and test conceptual, mathematical, physical, and empirical models.	**ESS1.B: Earth and the Solar System** ▪ Cyclical changes in the shape of Earth's orbit around the sun, together with changes in the tilt of the planet's axis of rotation, both occurring over hundreds of thousands of years, have altered the intensity and distribution of sunlight falling on the earth. These phenomena cause a cycle of ice ages and other gradual climate changes. (secondary to HS-ESS2-4) **ESS2.A: Earth Materials and Systems** ▪ Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. (HS-ESS2-1),(HS-ESS2-2) ▪ Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through	**Cause and Effect** ▪ Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. (HS-ESS2-4) **Energy and Matter** ▪ The total amount of energy and matter in closed systems is conserved. (HS-ESS2-6) ▪ Energy drives the cycling of matter within and between systems. (HS-ESS2-3) **Structure and Function** ▪ The functions and properties of natural and designed objects and systems can be inferred from their overall structure, the way their components are shaped and used, and the molecular substructures of its various materials. (HS-ESS2-5) **Stability and Change** ▪ Much of science deals with

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MS-ESS3 Earth and Human Activity

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Students who demonstrate understanding can: **MS-ESS3-1. Construct a scientific explanation based on evidence for how the uneven distributions of Earth's mineral, energy, and groundwater resources are the result of past and current geoscience processes.** [Clarification Statement: Emphasis is on how these resources are limited and typically non-renewable, and how their distributions are significantly changing as a result of removal by humans. Examples of uneven distributions of resources as a result of past processes include but are not limited to petroleum (locations of the burial of organic marine sediments and subsequent geologic traps), metal ores (locations of past volcanic and hydrothermal activity associated with subduction zones), and soil (locations of active weathering and/or deposition of rock).] **MS-ESS3-2. Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.** [Clarification Statement: Emphasis is on how some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions, but others, such as earthquakes, occur suddenly and with no notice, and thus are not yet predictable. Examples of natural hazards can be taken from interior processes (such as earthquakes and volcanic eruptions), surface processes (such as mass wasting and tsunamis), or severe weather events (such as hurricanes, tornadoes, and floods). Examples of data can include the locations, magnitudes, and frequencies of the natural hazards. Examples of technologies can be global (such as satellite systems to monitor hurricanes or forest fires) or local (such as building basements in tornado-prone regions or reservoirs to mitigate droughts).]
The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

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***Multiple DCIs show supplemental DCIs with three asterisks at the end of the DCI description. These are core ideas from other science disciplines that are important to understanding the DCI.
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Science and Engineering Practices

Analyzing and Interpreting Data

Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Analyze and interpret data to determine similarities and differences in findings. (MS-ESS3-2)

Constructing Explanations and Designing Solutions

Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in

Disciplinary Core Ideas

ESS3.A: Natural Resources

- Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geologic processes. (MS-ESS3-1)

ESS3.B: Natural Hazards

- Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Crosscutting Concepts

Patterns

- Graphs, charts, and images can be used to identify patterns in data. (MS-ESS3-2)

Cause and Effect

- Cause and effect relationships may be used to predict phenomena in natural or designed systems. (MS-ESS3-1)

Connections to Engineering, Technology, and Applications of Science

Influence of Science, Engineering, and Technology on Society and the Natural World

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment. (MS-ESS3-1)
- The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific

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