Real World Globes - Investigating the Seven Summits

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Collaborators:
Douglas Rogers (Real World Globes)

Purpose:

- To pinpoint the geographic locations of each continent's point of highest elevation.
- To elucidate the geotectonic mechanisms driving the uplift to form each summit.
- To identify and describe the local geology comprising and surrounding each summit.

Target Audience:

- High school students

Materials:

- 18" Geological Globe of the World™
- Clear 18" hemisphere
- Dry-erase markers, eraser
- Computer with internet access

Introduction:

The Earth is a moving, ever-changing, dynamic place. We as humans, with our short lifespans and comparatively recent evolution, have no conceptual or personal understanding of just how old the Earth is. We know from measuring radioisotope decay rates of various naturally-occurring elements that the Earth is around 4.543 billion years old. Given that humans have only existed on the planet for around 200,000 years, our existence only represents 0.0044% of the total age of the Earth! Barely a drop in the bucket.

However, we humans are clever and naturally curious creatures. Over the centuries we have developed and used science to our advantage to understand the world around us, how it has changed in the past, and what it will likely look like in the future. We as a species have a lot of say in that last part - but that discussion is for another time. Today, we will be investigating the ongoing geologic processes that have produced some of the most impressive mountain ranges on Earth, and within those mountain ranges, the highest point on each of the seven continents - the so-called "seven summits." As you will see during your investigation, there are actually several other summits that can be considered as the highest points, but these are a matter of debate depending on whether you are counting a continent as the primary landmass on a particular tectonic plate, or the entire plate itself. This is the case for Europe (Eurasian Plate) and Australia (Indo-Australian Plate).

Background:

In 1912 meteorologist Alfred Wegener described what he called "continental drift", an idea that culminated fifty years later in the modern theory of plate tectonics. Wegener noticed that the east coast of South America was a very close fit to the west coast of Africa. He surmised that long ago in the past these two continents were close to each other and fit together like pieces of a puzzle, but some process had caused these two continents to drift apart. Later in 1937, South African geologist Alexander du Toit further expanded on Wegener's theory by noticing that certain fossils of ferns could be found on both continents, indicating that they, at some point in time, shared a similar biogeographical distribution, lending further support to Wegener's theory of continental drift. As paleontologists looked at the biogeographical distribution of other fossils, they noticed similarities (see figures 1 and 2).

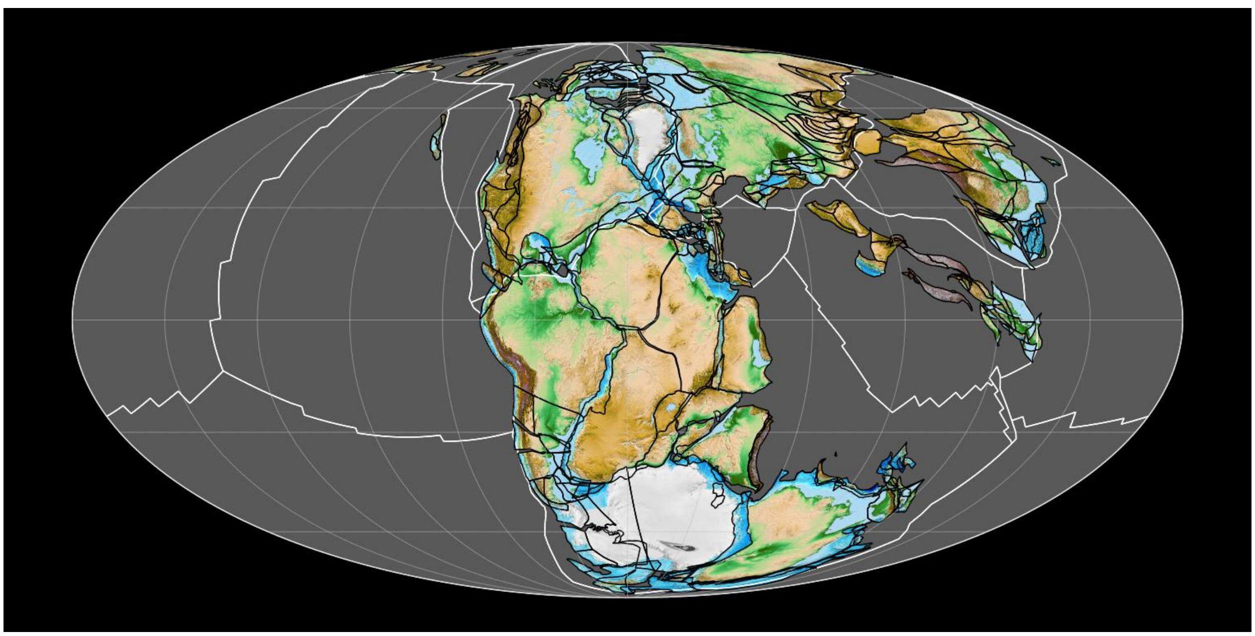


Figure 1: The supercontinent of Pangea, as viewed 200 million years ago during the Triassic period. One can clearly see how South America and Africa "fit" together, along with the other continents, like pieces of a puzzle. (Courtesy of Wikipedia (Fama Clamosa)).

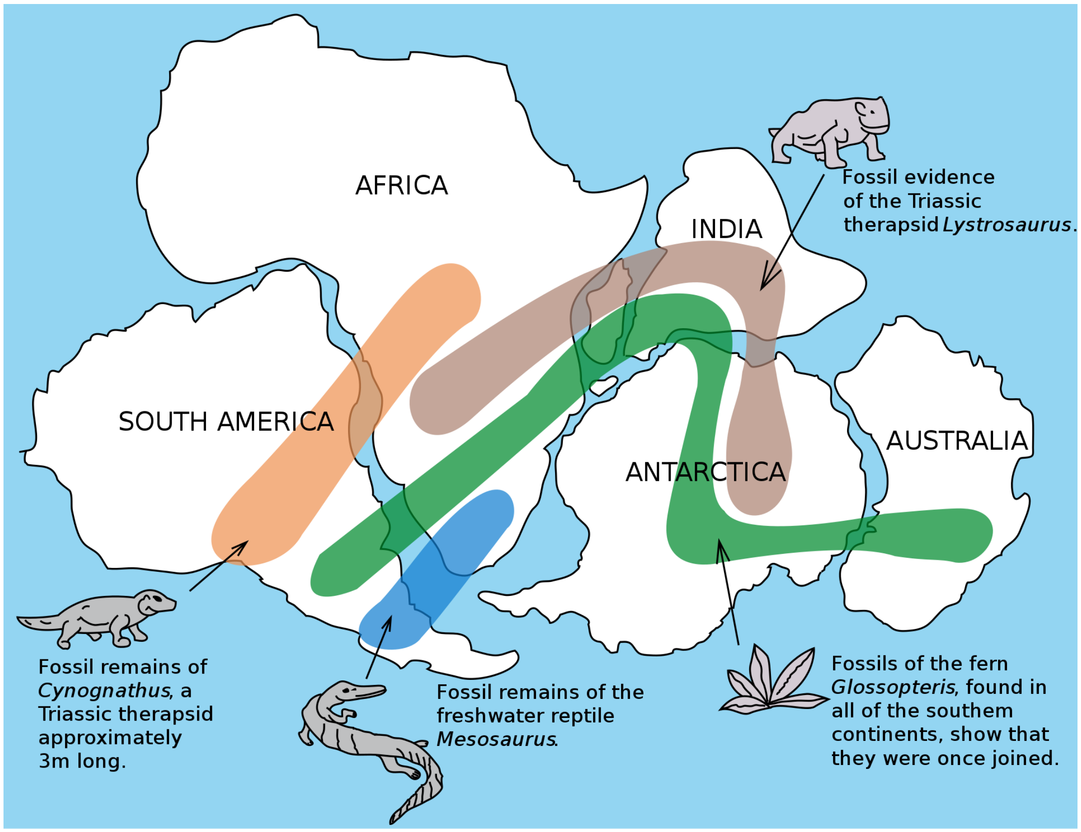


Figure 2: The Snider-Pellegrini-Wegener fossil map. This map shows biogeographic distribution of several different Triassic fossils across five continents joined together as the southern half of Pangea, known as Gondwana. Biogeographic distribution of fossils across multiple continents (now separated) is strong evidence for the existence of the supercontinent of Pangea, and supports Wegener's theory of continental drift. (Courtesy of Wikipedia (Osvaldocangaspadilla)).

So what do fossils have to do with mountains and high points? Well, in order to understand how these geographic high points came to be, it is important to understand how they are formed. In order to do this, we must first understand plate tectonics. The Earth's crust is divided up into 15 plates (see figure 3). These plates are in constant motion, some moving faster than others, and in different directions. Faults occur at the boundaries between plates. One type of fault (called a convergent fault) occurs when one plate slides underneath another plate (a process known as subduction). The result is an uplift of crustal rock on the overriding plate, which forms mountain ranges (see figure 4).

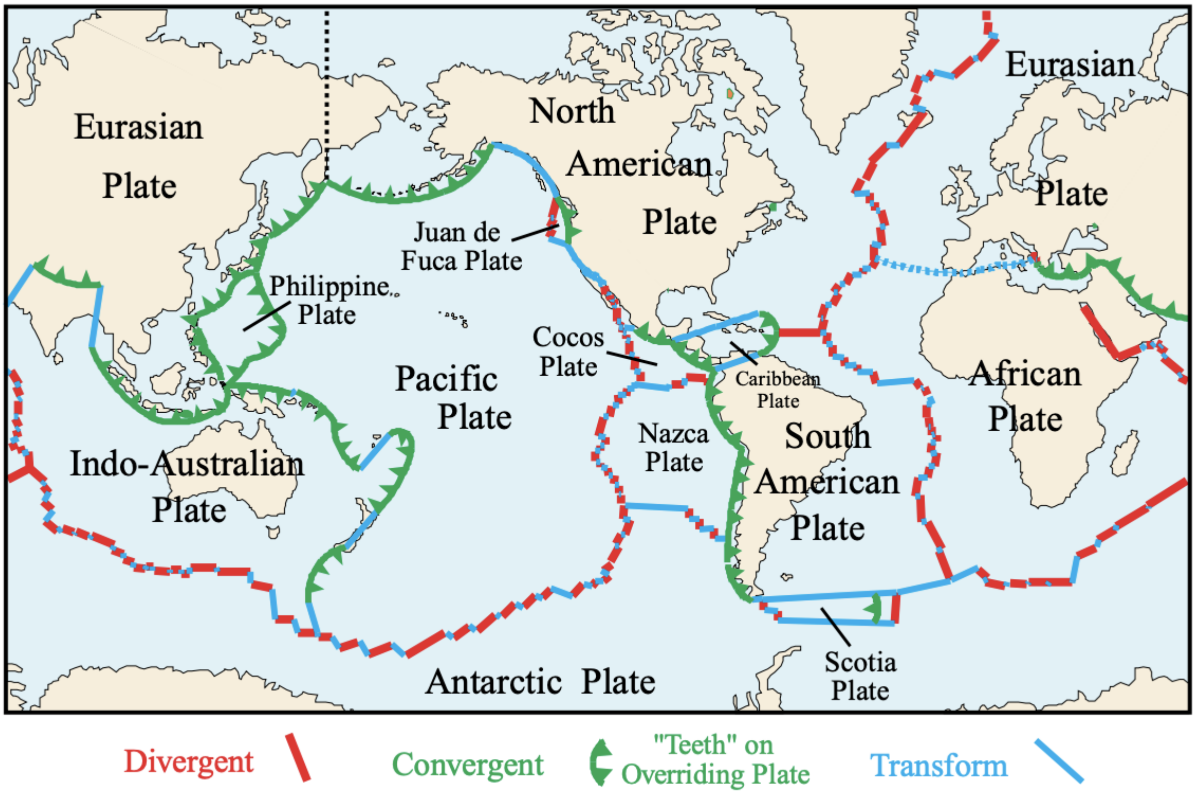


Figure 3: Map of the world's tectonic plates. There are 15 plates that make-up the Earth's crust. Faults occur at the boundaries of plates and can be classified as either divergent (spreading apart), convergent (coming together) or transform (sliding past each other). Mountain ranges and active volcanoes are often found at or near these faults. Earthquakes occur when plate movement occurs, and are often felt as the result of a release of the tensional energy stored up at the boundary between two plates. (Courtesy of USGS).

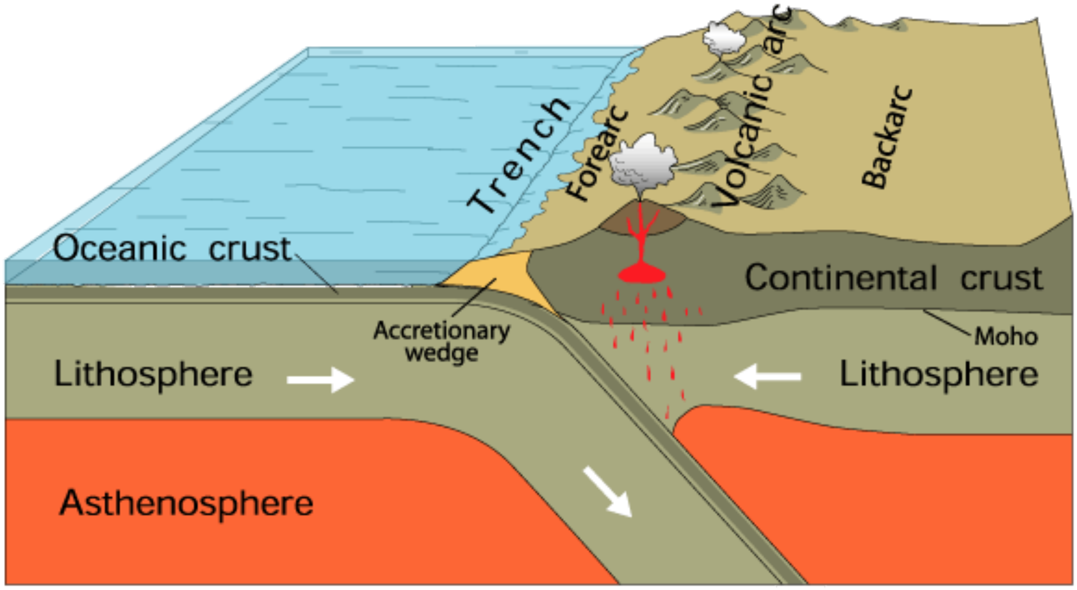


Figure 4: The process of plate subduction, where one plate slides underneath the other plate. This forces continental crust upward (uplift), producing a mountain range which often includes volcanoes. If oceanic crust slides under other oceanic crust, volcanic island chains can be formed. (Courtesy of McGraw-Hill Access Science).

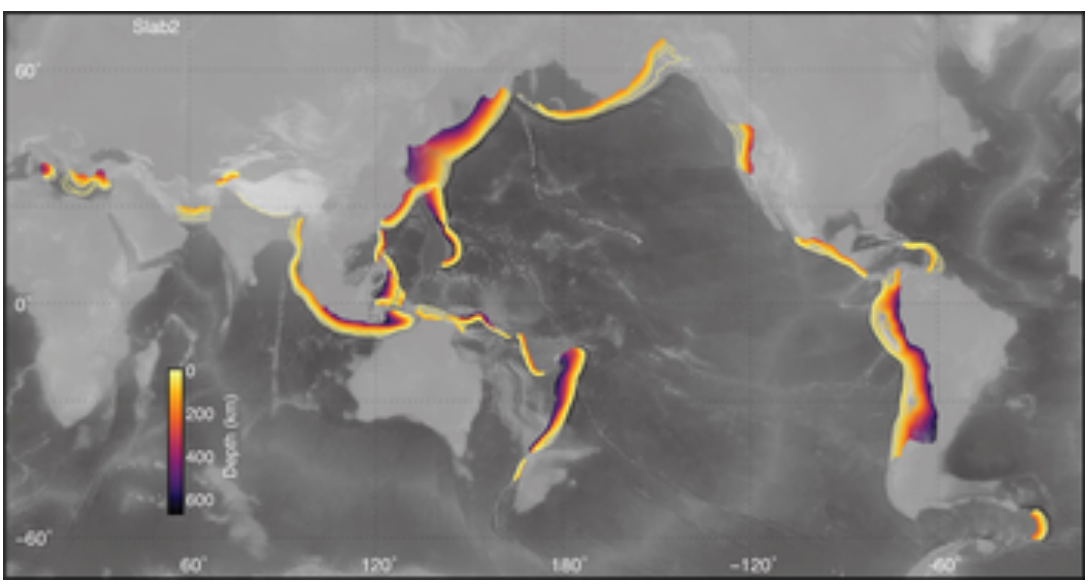


Figure 5: Subduction zones around the world. It is at these locations that many of the most geologically-active regions on Earth can be found, including the uplift of some of the most impressive mountain ranges such as the Himalaya and the Andes. (Courtesy of Gavin P. Hayes, USGS).

Now that we have an understanding of how uplift occurs as a result of the movement of tectonic plates, we can now begin locating and investigating the “seven summits” of the world!

Activity 1: Locating each of the seven summits

The list of the highest point on each continent, as well as its latitude and longitude, is given in the table below:

Continent	Highest Point	Elevation	Latitude	Longtitude
Asia	Mt. Everest	8,850 m (29,031 ft)	27°59′17″N	86°55′31″E
South America	Aconcagua	6,962 m (22,837 ft)	32°39′11.51″S	70°0′40.32″W
North America	Denali (formerly Mt. McKinley)	6,190 m (20,310 ft)	63°04′10″N	151°00′27″W
Africa	Kilimanjaro	5,895 m (19,341 ft)	03°04′33″S	37°21′12″E
Europe	Mt. Elbrus	5,642 m (18,510 ft)	43°21′18″N	42°26′21″E
Oceania	Puncak Jaya/Carstensz Pyramid	4,884 m (16,024 ft)	04°04′44″S	137°9′30″E
Antarctica	Mt. Vinson/Vinson Massif	4,892 m (16,050 ft)	78°31′31.74″S	85°37′1.73″W

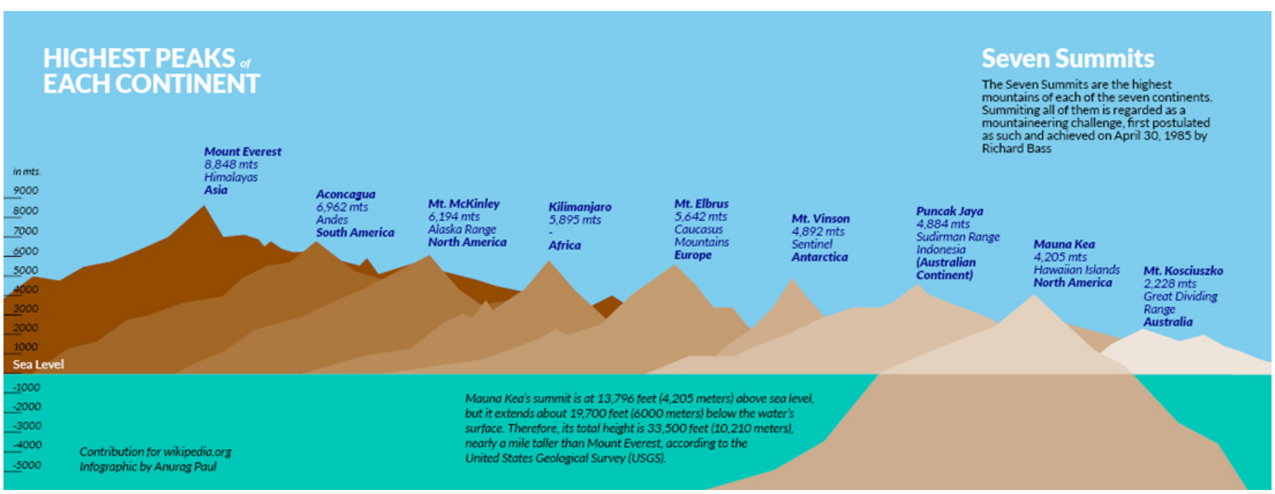


Figure 6: A scale comparison of the elevations of each of the seven summits (Mauna Kea in Hawaii and Mt. Kosciuszko in Australia are also often included). (Courtesy of Wikipedia (Anurag Paul).

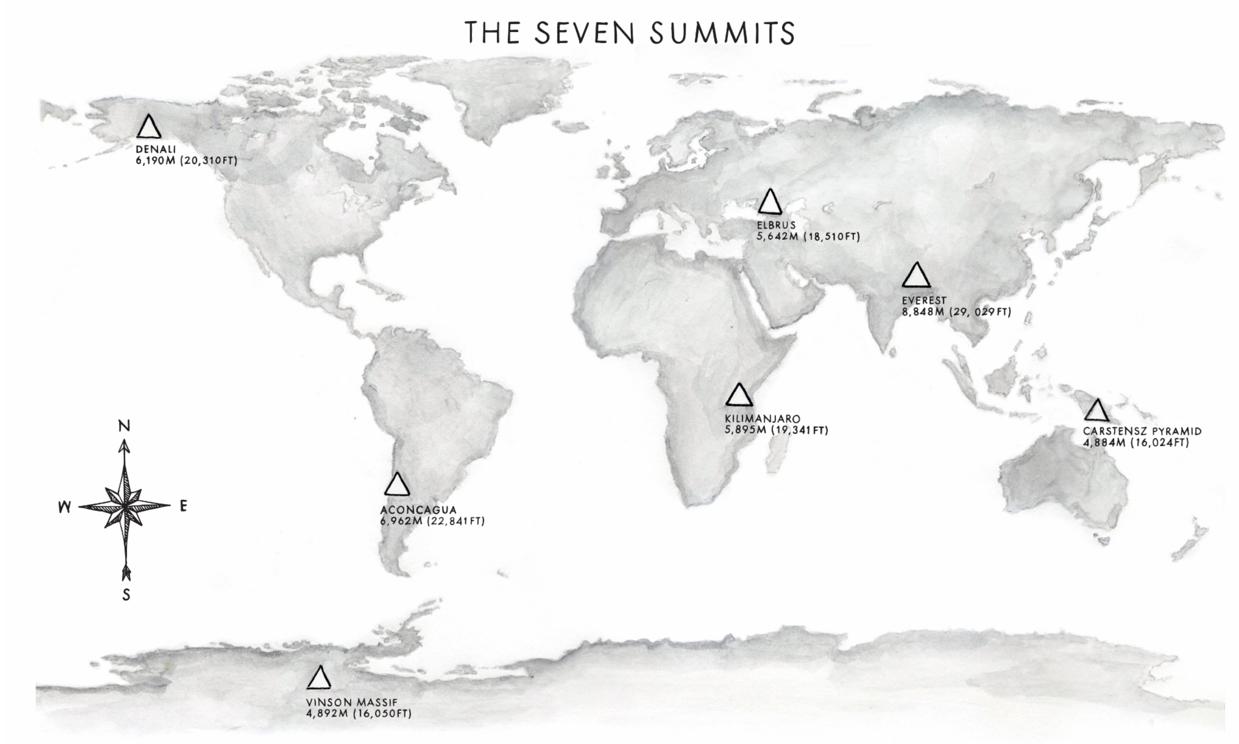


Figure 7: Map locations of the seven summits. (Courtesy of Geordie Stewart).

For this first activity please be sure that the clear plastic hemispheres are secured onto the globe so that you may write on it using a dry erase marker. Using the latitude and longitude given for each summit in the table on page 6, locate each summit on the globe and circle it using your dry erase marker. If you are having trouble finding the location using the latitude and longitude coordinates, you may use the map above (figure 7) to help you.

Once you have completed this task, have someone in your group raise their hand to call the teacher over. Please have the teacher verify that each summit has been correctly located and circled on the globe. Once your group has done this you may proceed to Activity 2.

Activity 2: Tectonic plate activity associated with each summit

In this activity your group will be determining which tectonic plate(s) is/are responsible for the uplift that created the mountain range in which that particular summit is located. You may fill out the table below. Use figure 8 (on the next page) to help you. (*Note: Some summits are not located near a plate boundary. For these summits, simply list the name of the tectonic plate it is located on.*)

Continent	**Highest Point**	**Tectonic Plate(s) involved in uplift**	**Type of fault activity** (divergent, convergent, transform)
Asia	Mt. Everest		
South America	Aconcagua		
North America	Denali (formerly Mt. McKinley)		
Africa	Kilimanjaro		
Europe	Mt. Elbrus		
Oceania	Puncak Jaya/Mt. Carstensz		
Antarctica	Mt. Vinson/Vinson Massif		

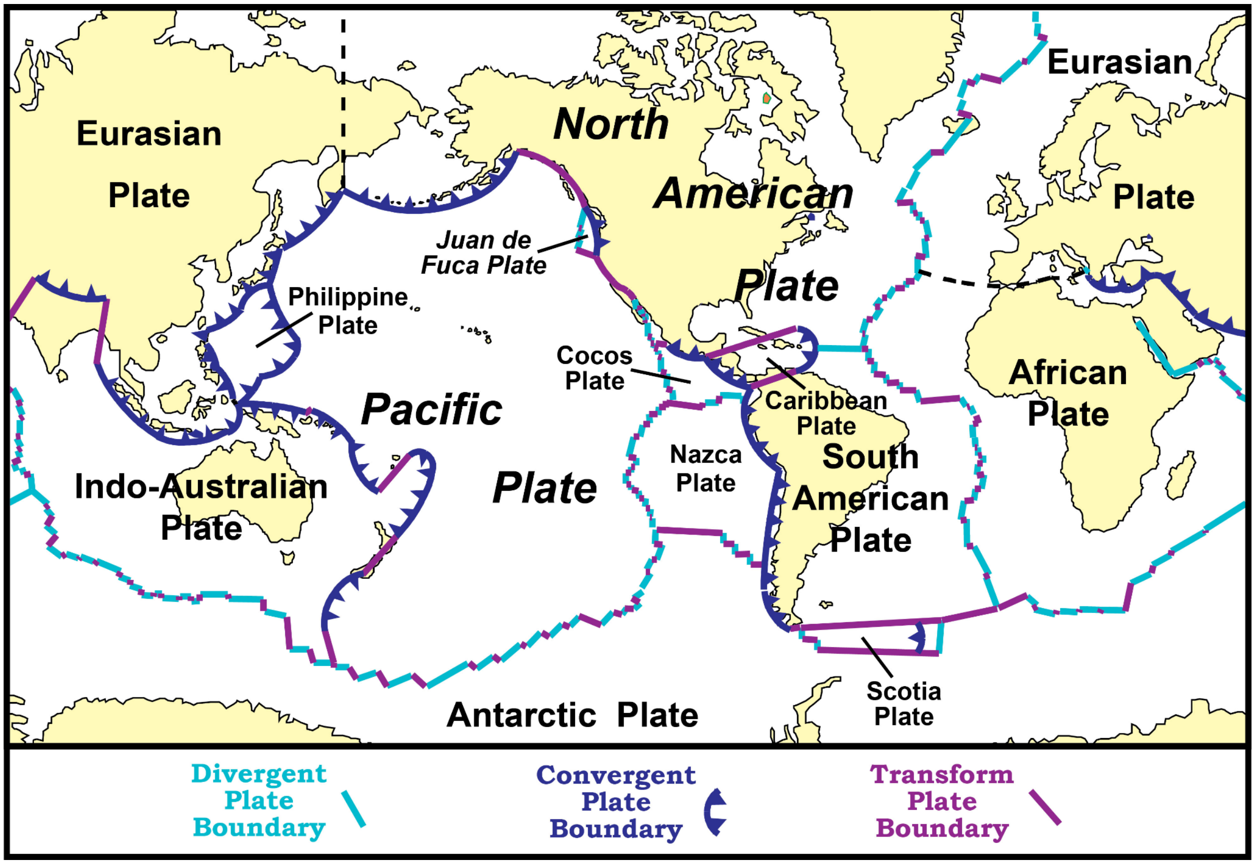


Figure 8: Tectonic plate names and locations. Subduction (convergent) zones are shown in dark blue lines with triangles on the overlying plate in the direction which the underlying plate is sliding. Divergent plate boundaries are where the two plates are moving apart. Transform plate boundaries are where the two plates are sliding past each other. (Courtesy of The National Park Service).

Activity 3: Regional geology of each summit

In this activity your group will be using the globe to determine the primary geology that comprises each of the seven summits. In a later assignment your group will be asked to research and present on the geology of one particular summit of your choosing. The presentation should include information on this particular type of rock, its physical characteristics, chemical makeup, geographic distribution, and age. Your teacher will provide more detailed guidelines for this follow-up assignment at a later date.

Using the globe, please fill in the table below. You may use the color-coded key (on the next page) to help you identify the rock type and age.

Continent	**Highest Point**	**Primary type of rock and age**	**Secondary type of rock** (immediate geographic surroundings, if different)
Asia	Mt. Everest		
South America	Aconcagua		
North America	Denali (formerly Mt. McKinley)		
Africa	Kilimanjaro		
Europe	Mt. Elbrus		
Oceania	Puncak Jaya/Mt. Carstensz		
Antarctica	Mt. Vinson/Vinson Massif		

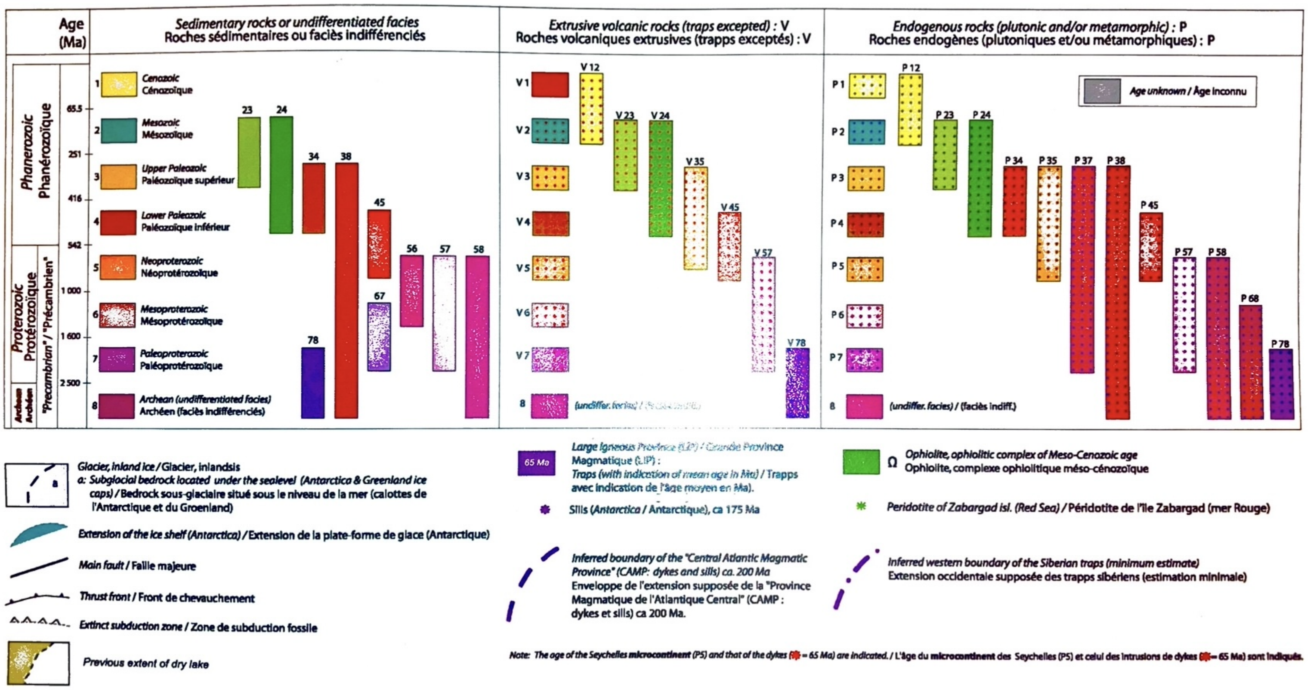
Our group is choosing this summit to present on its geology: ____________________________

GEOLOGICAL GLOBE OF THE WORLD

GLOBE GÉOLOGIQUE DU MONDE

ONSHORE AREAS / ZONES ÉMERGÉES

(*except Iceland* / sauf Islande)



Hotspots

I. Currently active hotspots, or hotspots whose ultimate known activity settles within the last million years or so.

- ○ 1. *HA, ... HG: "Primary" hotspots i.e. assumed to correspond to a deep seated thermal plume (after Courtillot et al. , 2003).*
- ○ 2. *Hh, ... Hi: Possible "primary" hotspots* (ibid.).
- o 3. *H1, ... H34: Other "hotspots" , i.e. assumed to have a relatively shallow mantle origin (upper/lower mantle transition zone, "hotline", passive lithosphere breakup, ...) or whose deeper origin is yet questionable.*

II. ○ eH1 & eH2: Hotspots whose extinction is much older.

HA: Afar - HB: Easter - HC: Hawaii - HD: Iceland - HE: Louisville - HF: Reunion - HG: Tristan.

Hh: Galapagos - Hi: Kerguelen.

H1: Arago seamount (smt) - H2: Ascension - H3: Azores - H4: Balleny - H5: Bouvet - H6: Bowie/ Kodiak smts H7: Cameroon - H8: Canary - H9: Cape Verde - H10: Caroline - H11: Comores - H12: Crozet - H13: Darfur/ Jebel Marra - H14: Fernando de Noronha - H15: Foundation smt - H16: Flinders smt/ Lord Howe Rise - H17: Hoggar H18: Jan Mayen - H19: Juan de Fuca/Cobb - H20: Juan Fernandez/A. Selkirk - H21: Macdonald - H22: Marion H23: Marquesas - H24: Pitcairn - H25: Rarotonga - H26: St Paul/Amsterdam - H27: Samoa - H28: San Felix/ Desventuradas - H29: Socorro/Revillagigedo - H30: Tahiti/Society - H31: Tasmanid - H32: Tibesti - H33: Trindade/ Martin Vaz - H34: Yellowstone.

eH1: Great Meteor smt/ New England smts - eH2: St. Helena.

Follow-up questions:

1. How do plate tectonics relate to the formation of mountain ranges? Are mountain ranges always found at the boundaries of tectonic plates? If not, can you provide an example of a mountain range that is NOT found at the boundary between two plates?

2. Some mountain ranges, such as the southern alps on the south island of New Zealand, are not formed from convergence (subduction), but rather through the process of transformation (sliding of plates past each other). How might mountains be formed from a process like this?

3. Was each summit that you located homogeneous (the same throughout) in terms of its composition? (In other words, was each summit made out of the same type of rock throughout?)

4. Was there any correlation between the elevation of a particular summit and its rock composition?

5. What processes do you think contribute to the erosion (wearing down) of mountains?

6. If the rate at which a mountain is being eroded equals the rate at which a mountain is being uplifted, what will happen to the elevation of the mountain over time?

7. Which mountain range do you think is older: North America's Rocky Mountains or Asia's Himalayas? What differences between the two mountain ranges did you use that helped you answer this question?

8. On Mars, there are no plate tectonics and there is no evidence of any recent volcanic activity. However, Mars has an atmosphere and winds. Do you think the mountains on Mars are growing or shrinking? Explain your answer.

Supplementary activity (optional):

In addition to the seven summits listed in this activity, there are two additional summits that are sometimes included as continental high points (bringing the total to nine summits). These are:

- Mont Blanc (Europe)
- Mt. Kosciuszko (Australia)

The inclusion or exclusion of these summits depends on how the continental high point is defined.

In the table below, please use the latitude and longitude coordinates to locate these two summits on the globe. Circle them using the dry erase marker.

Continent	Highest Point	Elevation	Latitude	Longtitude
Europe	Mont Blanc	4,808 m (15,774 ft)	45°50′0″N	6°52′2″E
Australia	Mt. Kosciuszko	2,228 m (7,310 ft)	36°27′21″S	148°15′49″E

Now, given each mountain's location, use figure 8 to determine what are the likely tectonics involved.

Continent	Highest Point	Tectonic Plate(s) involved in uplift	Type of fault activity (divergent, convergent, transform)
Europe	Mont Blanc		
Australia	Mt. Kosciuszko*	None	N/A

*Note: Mt. Kosciuszko (part of the Australian Alps) was not formed by tectonic uplifting, but rather was the result of the upward displacement of magma during the breakup of Gondwana between 130 and 160 million years ago.

Finally, using the globe, determine the primary rock type (and surrounding rock types, if applicable) composing each mountain. Again, use the color-coded key found on page 11 to help you with rock identification.

Continent	**Highest Point**	**Primary type of rock**	**Secondary type of rock** (immediate geographic surroundings, if different)
Europe	Mont Blanc		
Australia	Mt. Kosciuszko		

Other useful resources (online):

- General geologic map of the world
- OneGeology Portal
- Geologic time scale

Grades Nine through Twelve
Standards Arranged by Disciplinary Core Ideas

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*.

The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

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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Connections to other DCIs in this grade-band: **HS.PS1.A** (HS-ESS2-5),(HS-ESS2-6); **HS.PS1.B** (HS-ESS2-5),(HS-ESS2-6); **HS.PS2.B** (HS-ESS2-1),(HS-ESS2-3); **HS.PS3.A** (HS-ESS2-4); **HS.PS3.B** (HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-5); **HS.PS3.D** (HS-ESS2-3),(HS-ESS2-6); **HS.PS4.B** (HS-ESS2-2); **HS.LS1.C** (HS-ESS2-6); **HS.LS2.A** (HS-ESS2-7); **HS.LS2.B** (HS-ESS2-2),(HS-ESS2-6); **HS.LS2.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7); **HS.LS4.A** (HS-ESS2-7); **HS.LS4.B** (HS-ESS2-7); **HS.LS4.C** (HS-ESS2-7); **HS.LS4.D** (HS-ESS2-2),(HS-ESS2-7); **HS.ESS1.C** (HS-ESS2-4); **HS.ESS3.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); **HS.ESS3.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6)
Articulation of DCIs across grade-bands: **MS.PS1.A** (HS-ESS2-3),(HS-ESS2-5),(HS-ESS2-6); **MS.PS1.B** (HS-ESS2-3); **MS.PS2.B** (HS-ESS2-1),(HS-ESS2-3); **MS.PS3.A** (HS-ESS2-3),(HS-ESS2-4); **MS.PS3.B** (HS-ESS2-3),(HS-ESS2-4); **MS.PS3.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); **MS.PS4.B** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6); **MS.LS1.C** (HS-ESS2-4); **MS.LS2.A** (HS-ESS2-7); **MS.LS2.B** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6); **MS.LS2.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-7); **MS.LS4.A** (HS-ESS2-7); **MS.LS4.B** (HS-ESS2-7); **MS.LS4.C** (HS-ESS2-2),(HS-ESS2-7); **MS.ESS1.C** (HS-ESS2-1),(HS-ESS2-7); **MS.ESS2.A** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7); **MS.ESS2.B** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6); **MS.ESS2.C** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5),(HS-ESS2-6),(HS-ESS2-7); **MS.ESS2.D** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-5); **MS.ESS2.E** (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-5),(HS-ESS2-6); **MS.ESS3.C** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6),(HS-ESS2-7); **MS.ESS3.D** (HS-ESS2-2),(HS-ESS2-4),(HS-ESS2-6)

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California Common Core State Standards Connections:

ELA/Literacy –

RST.11-12.1	Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (HS-ESS2-2),(HS-ESS2-3)
RST.11-12.2	Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (HS-ESS2-2)
WHST.9–12.1.a–e	Write arguments focused on *discipline-specific content*. (HS-ESS2-7)
WHST.9–12.7	Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. (HS-ESS2-5)
SL.11-12.5	Make strategic use of digital media (e.g., textual, graphical, audio, visual, and interactive elements) in presentations to enhance understanding of findings, reasoning, and evidence and to add interest. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-4)

Mathematics –

MP.2	Reason abstractly and quantitatively. (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)
MP.4	Model with mathematics. (HS-ESS2-1),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)
N-Q.1-3	Reason quantitatively and use units to solve problems.★ (HS-ESS2-1),(HS-ESS2-2),(HS-ESS2-3),(HS-ESS2-4),(HS-ESS2-6)

MS-ESS2 Earth's Systems

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Students who demonstrate understanding can: **MS-ESS2-1. Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.** [Clarification Statement: Emphasis is on the processes of melting, crystallization, weathering, deformation, and sedimentation, which act together to form minerals and rocks through the cycling of Earth's materials.] [Assessment Boundary: Assessment does not include the identification and naming of minerals.] **MS-ESS2-2. Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.] **MS-ESS2-3. Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.** [Clarification Statement: Examples of data include similarities of rock and fossil types on different continents, the shapes of the continents (including continental shelves), and the locations of ocean structures (such as ridges, fracture zones, and trenches).] [Assessment Boundary: Paleomagnetic anomalies in oceanic and continental crust are not assessed.]
The performance expectations above were developed using the following elements from the NRC document *A Framework for K–12 Science Education*:

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

California's Next Generation Science Standards (NGSS) for K–12
Alternative Discipline Specific Course
Grade Six – Earth and Space Sciences

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. ▪ Develop and use a model to describe phenomena. (MS-ESS2-1) **Analyzing and Interpreting Data** Analyzing data in 6–8 builds on K–5 experiences 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 provide evidence for phenomena. (MS-ESS2-3) **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,	**ESS1.C: The History of Planet Earth** ▪ Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches. (HS.ESS1.C GBE) (secondary to MS-ESS2-3) **ESS2.A: Earth's Materials and Systems** ▪ All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. (MS-ESS2-1) ****Supplemental DCI PS1.A* ▪ The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2) **ESS2.B: Plate Tectonics and Large-**	**Patterns** ▪ Patterns in rates of change and other numerical relationships can provide information about natural and human designed systems. (MS-ESS2-3) **Scale Proportion and Quantity** ▪ Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-ESS2-2) **Stability and Change** ▪ Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales. (MS-ESS2-1)

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Connections to other DCIs in this grade-band: **MS.PS1.A** (MS-ESS2-1); **MS.PS1.B** (MS-ESS2-1),(MS-ESS2-2); **MS.PS3.B** (MS-ESS2-1); **MS.LS2.B** (MS-ESS2-1),(MS-ESS2-2); **MS.LS2.C** (MS-ESS2-1); **MS.LS4.A** (MS-ESS2-3); **MS.ESS3.C** (MS-ESS2-1)
Articulation of DCIs across grade-bands: **3.LS4.A** (MS-ESS2-3); **3.ESS3.B** (MS-ESS2-3); **4.PS3.B** (MS-ESS2-1); **4.ESS1.C** (MS-ESS2-2),(MS-ESS2-3); **4.ESS2.A** (MS-ESS2-1),(MS-ESS2-2); **4.ESS2.B** (MS-ESS2-3); **4.ESS2.E** (MS-ESS2-2); **4.ESS3.B** (MS-ESS2-3); **5.ESS2.A** (MS-ESS2-1),(MS-ESS2-2); **HS.PS1.B** (MS-ESS2-1);; **HS.PS3.B** (MS-ESS2-1); **HS.PS3.D** (MS-ESS2-2); **HS.LS1.C** (MS-ESS2-1); **HS.LS2.B** (MS-ESS2-1),(MS-ESS2-2); **HS.LS4.A** (MS-ESS2-3); **HS.LS4.C** (MS-ESS2-3); **HS.ESS1.C** (MS-ESS2-2),(MS-ESS2-3); **HS.ESS2.A** (MS-ESS2-1),(MS-ESS2-2),(MS-ESS2-3); **HS.ESS2.B** (MS-ESS2-2),(MS-ESS2-3); **HS.ESS2.C** (MS-ESS2-1),(MS-ESS2-2); **HS.ESS2.D** (MS-ESS2-2); **HS.ESS2.E** (MS-ESS2-1),(MS-ESS2-2); **HS.ESS3.D** (MS-ESS2-2)

California Common Core State Standards Connections:

ELA/Literacy –

RST.6–8.1	Cite specific textual evidence to support analysis of science and technical texts. (MS-ESS2-2),(MS-ESS2-3)
RST.6–8.7	Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-ESS2-3)
RST.6–8.9	Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-ESS2-3)
WHST.6–8.2.a–f	Write informative/explanatory texts to examine a topic and convey ideas, concepts, and information through the selection, organization, and analysis of relevant content. (MS-ESS2-2)
SL.8.5	Integrate multimedia components and visual displays in presentations to clarify claims and findings and emphasize salient points. (MS-ESS2-1),(MS-ESS2-2)

Mathematics –

MP.2	Reason abstractly and quantitatively. (MS-ESS2-2),(MS-ESS2-3)
6.EE.6	Use variables to represent numbers and write expressions when solving a real-world or mathematical problem; understand that a variable can represent an unknown number, or, depending on the purpose at hand, any number in a specified set. (MS-ESS2-2),(MS-ESS2-3)
7.EE.4.a,b	Use variables to represent quantities in a real-world or mathematical problem, and construct simple equations and inequalities to solve problems by reasoning about the quantities. (MS-ESS2-2),(MS-ESS2-3)