Story 1

Geology and Geography: Where Are We Going and Why?

Dr. Tanya Atwater
Professor, Geological Sciences
University of California at Santa Barbara

Research Focus

What is the plate tectonic history of western North America and how does it relate to the area's underwater and dry land geology?

Dr. Bob Ballard
Chief Scientist and Founder
JASON Foundation for Education

Team JASON Online	Video	Live Broadcast
• **Digital Lab:** Earth Systems • Geology and Geography Story Page • Chat Sessions • Message Boards	• Location, Location, Location: Geologic History	Use JASON XIV components to prepare for the live broadcast. Visit Team JASON Online for the latest details.

In Story 1, which covers the **geography and natural history** of the Channel Islands, you'll consider how the islands' geographic location determines their environment. With help from host researcher Tanya Atwater, you'll think about how the Channel Islands were formed and how they are geologically connected to the California mainland. You'll also see how life around the islands depends on ocean currents and gain an appreciation for the diversity of living creatures that live there.

Geology and Geography: Where Are We Going and Why?

Research Article

Where Are We Going and Why? ..... page 23

Exercise 1.1: Geography — **Bathymetry, Geologic History**
1½ hours (two 45-minute periods) — ***Model Building, Communicating***

The Mystery of the Pygmy Mammoth ..... page 27

Students will build a three-dimensional model of a part of the Channel Island's underwater landscape, including the bathymetry of areas that are currently under water. They will then use this model to determine whether the prehistoric mammoth swam or walked to the Channel Islands during the last ice age.

Exercise 1.2: Geology — **Plate Tectonics**
1½ hours (two 45-minute periods) — ***Model Building, Drawing Conclusions***

Plate Tectonics Jigsaw ..... page 32

Students will build a paper model of the tectonic plates, faults, and blocks in the southern California area. They then use this model to learn about the geologic history of the Channel Islands and explain some of the islands' unusual geologic features.

Exercise 1.3: Math, Geography, Ecology — **Biodiversity, Endemic and Alien Species**
1½ hours (two 45-minute periods) — ***Organizing Information, Estimating Values***

Surveying the Channel Islands ..... page 36

This activity challenges students to develop hypotheses about how the biodiversity of the different Channel Islands is related to two geographical factors: size and distance from the mainland. The students will estimate the necessary geographic information using their map-reading skills.

Student Self-Assessment
45 minutes — ***Organizing Information, Communicating***

Adopt an Island ..... page 40

Students will collect and synthesize what they've learned about the different Channel Islands and research additional information. Each student will focus on one island, delivering a presentation about how that island is different from and similar to all the other Channel Islands.

> *"The theory of plate tectonics is a really good way to start learning about the Earth. It explains why most of the earthquakes and volcanoes happen. It explains why there are ocean basins and continents and mountain belts. It makes it fun to look at the world map."*
>
> **—Tanya Atwater,**
> **JASON host researcher**

STANDARDS AND ASSESSMENT

Student Name: _____

National Education Standards	Exercise
Science Standard A: Science As Inquiry Students should learn about scientific inquiry and develop the abilities necessary to perform it.	The Mystery of the Pygmy Mammoth Plate Tectonics Jigsaw Surveying the Channel Islands
Science Standard D: Earth and Space Science Students should develop an understanding of the structure of the Earth system, Earth's history, and the relationship of Earth to the rest of the solar system.	The Mystery of the Pygmy Mammoth Plate Tectonics Jigsaw
Science Standard G: History and Nature of Science Students should develop an understanding about the nature and history of science and learn that science is a human endeavor.	The Mystery of the Pygmy Mammoth
Geography Standard 1: The World in Spatial Terms Students should learn to use maps and other geographic representations, tools, and technologies to acquire, process, and report information from a spatial perspective.	The Mystery of the Pygmy Mammoth Plate Tectonics Jigsaw Surveying the Channel Islands
Geography Standard 7: Physical Systems Students should learn about the physical processes that shape the patterns of Earth's surface.	The Mystery of the Pygmy Mammoth Plate Tectonics Jigsaw
Geography Standard 8: Physical Systems Students should learn about the characteristics and spatial distribution of ecosystems on Earth's surface.	Plate Tectonics Jigsaw
Math Standard: Problem Solving Students should develop an understanding of mathematical concepts by working through problems that allow applications of mathematics to other contexts.	Surveying the Channel Islands
Math Standard: Geometry Students should develop an understanding of the characteristics and properties of two-and three-dimensional shapes, transformations, and symmetry, as well as develop their use of visual and spatial reasoning to solve problems.	Surveying the Channel Islands

Performance Indicators: The Mystery of the Pygmy Mammoth	**Novice**	**Apprentice**	**Researcher**
Transforms a two-dimensional bathymetric map into a three-dimensional model.			
Uses the model to make a judgement between two competing scientific hypotheses.			
Performance Indicators: Plate Tectonics Jigsaw	**Novice**	**Apprentice**	**Researcher**
Simulates the geologic history of the Channel Islands region using a paper model.			
Uses the model to explain unusual geologic features of the Channel Islands region.			
Performance Indicators: Surveying the Channel Islands	**Novice**	**Apprentice**	**Researcher**
Estimates the areas of the Channel Islands and other local regions.			
Develops hypotheses to explain the relationships between the different geographic properties of the Channel Islands (area, remoteness, biodiversity).			

Student Self-Assessment: Adopt an Island
Skills: Organizing information, communicating

	Score
Multiple Choice Test—Team JASON Online at www.jasonproject.org	

Teacher preparation

Where Are We Going and Why?

Focus *questions*

How are the Channel Islands similar to and different from mainland California?

How did the Channel Islands come to be and how did plants and animals populate them?

What global-scale processes affect the Channel Islands?

Los Angeles, the urban heart of southern California, is home to nearly 10 million people. It might seem like an unlikely starting point for this year's JASON expedition. After all, if you leave the city by one of its many freeways, you'll cross miles of familiar ground: shopping malls and housing developments, industries and office parks. But with JASON host researchers Tanya Atwater and Robert Ballard, you'll leave by boat to discover one of California's hidden treasures: the fascinating world of the Channel Islands.

Where are the California Channel Islands?

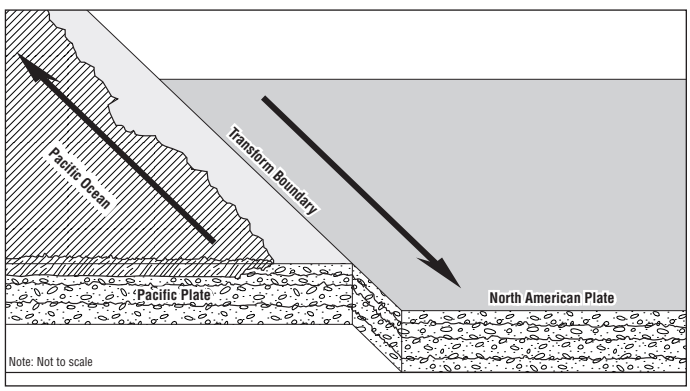
Take a look at Map 1 in the JASON Atlas. If you follow the coastline, you'll see that it travels in a relatively straight, southeasterly direction before reaching a corner. That corner, named Point Conception, marks the boundary between southern California and the rest of the state. There, the coastline jogs eastward to Santa Barbara and Los Angeles before swinging southward again to San Diego and resuming its original direction. In the waters between these three cities lie California's eight Channel Islands.

Now that you know where the Channel Islands are, you're ready to learn about what makes the area so exciting for scientists and explorers. We'll start with a topic relating to Dr. Atwater's research.

What makes the Channel Islands area so interesting to geologists?

Did you know that the Channel Islands, as well as all the top layers of rock on Earth's crust, are lying on top of plates? These **tectonic plates** are hard and brittle like dinner plates at home, but there the similarity ends. They are irregular in shape, not round—and instead of being several inches wide, many of these deep rock plates are bigger than an entire **continent!** Because of heat currents circulating deep within Earth, these plates are constantly moving. They have been sliding and jostling against each other for many millions of years, building up mountain ranges and shaping oceans as they go.

For geologists like Dr. Atwater, the most fascinating regions of Earth include the places where two different tectonic plates meet and interact with each other. The Channel Islands are near one of these places—a line separating the Pacific and the North American Plates called a **transform boundary.** At a transform boundary, tectonic plates mainly slide past each other (although they also push against each other in places). The Pacific Plate (carrying much of the coast of California) is slowly moving to the northwest while the North American Plate (carrying the rest of the continent of North America) is slowly moving to the southeast. California's transform boundary is also known as the San Andreas Fault. This fault is famous because it is the main reason why California gets so many earthquakes.



A simplified illustration of motion along the San Andreas fault.

Research article

Are there still unexplored areas around the Channel Islands?

Although they ride on top of the Pacific Plate, the Channel Islands are on the western edge of the continent of North America. Marine geologists like Dr. Ballard have a special name for this region of North America: they call it the California Borderland. It might seem strange to think of the Channel Islands as part of North America, since they are cut off from the mainland by water. But the name would make immediate sense if you could somehow drain some of the water out of the oceans and walk out to the islands. You'd find a new landscape of mountain ridges and deep valleys stretching out to the true edge of North America: a dramatic slope dropping thousands of meters into the deep basin of the Pacific Ocean. Because this landscape is hidden by the water, there is a lot we still don't know about it. Marine geologists are just beginning their exploration of this vast underwater realm.

Why are there so many different marine species living around the Channel Islands?

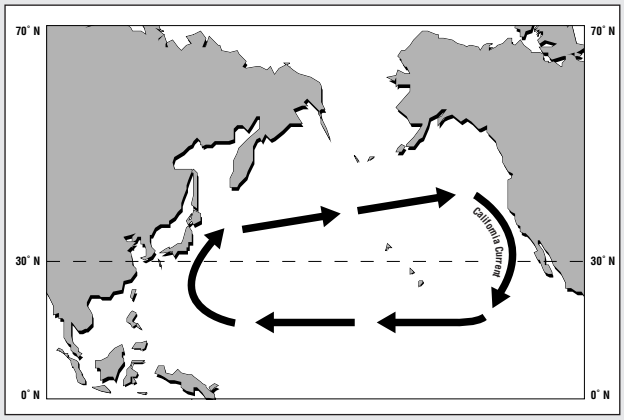
In addition to being on the outermost edge of the North American continent, the islands are at the boundary between two different climates: the cooler, wetter climate of northern California and the warmer, drier climate of southern California. Why is the boundary here and not somewhere else? One important factor is the behavior of a very large flow of cool (9° to 16° Celsius/48° to 61° Fahrenheit) water called the **California Current.** It starts in the cold Northern Pacific and flows south toward the warmer waters west of Mexico. Along most of this coast, the California Current flows very close to land. It's part of the reason why the coastal temperature of California is more moderate than its geographical position would suggest.

Right at Point Conception, the coastline turns a corner, allowing warmer currents to flow into the gap between the California Current and the coastline (see Atlas Map 4). Because the Channel Islands are right where colder northern ocean currents mix with warmer southern currents, their marine environment supports an astonishing variety of marine species.

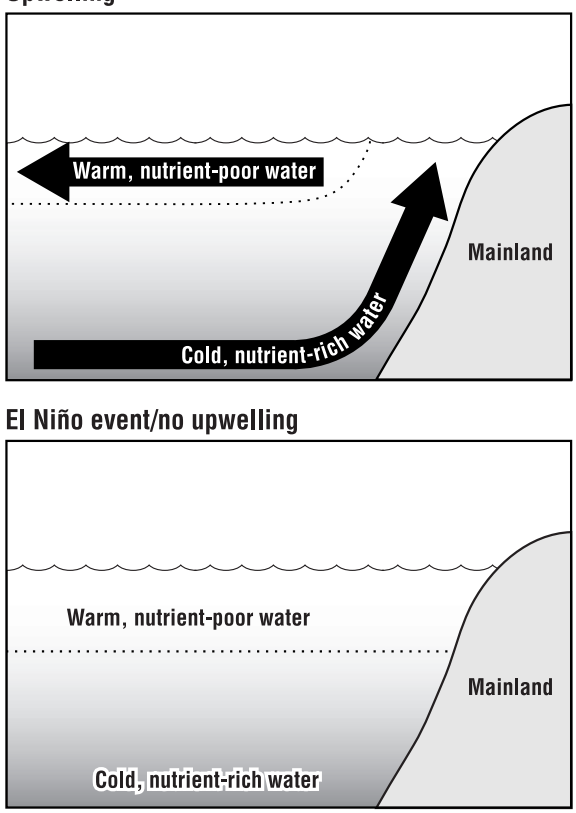
Another reason why the waters around the Channel Islands are so rich with marine life is a process called

The North Pacific Gyre

The California Current is part of a larger loop of ocean currents in the northern half of the Pacific Ocean. This clockwise loop (also called a gyre) flows east from Japan to North America, south along the California coast, back west across the Pacific, then north again to Japan.



The North Pacific Gyre moves water between Asia and North America.



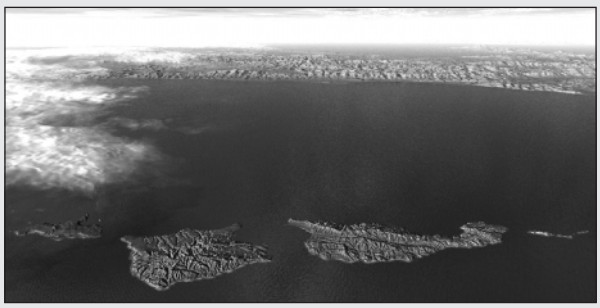
During an El Niño event, normal patterns of upwelling are disrupted.

Why Does Hot Water Float on Cold Water?

As water heats up, it expands slightly. This means that identical masses of water, each weighing exactly the same amount but having different temperatures, can have different volumes. Hot water weighs as much as cold water but takes up more room: it is less dense. Less-dense liquids always float on more-dense liquids. For example, 500 grams of hot water would float on top of 100 grams of cold water!

About Names

We focus on the four northernmost Channel Islands: San Miguel, Santa Rosa, Santa Cruz, and Anacapa. For the sake of simplicity, we'll mainly use the term "Channel Islands" to refer to just these four islands. Most of the land on these four islands is part of Channel Islands National Park. The surrounding waters are part of Channel Islands National Marine Sanctuary.



The four northernmost Channel Islands, from above and looking northward.

In all the world, the Torrey pine tree grows only on Santa Rosa Island and in a few groves north of San Diego.

The gloved hand of a biologist cradles a rare island fox.

upwelling. Upwelling carries colder water from the depths of the ocean up to areas that are shallow and sunlit. In the Channel Islands area, upwelling is caused by strong winds that blow along the coast between March and September. Before these winds arrive, there is a layer of sun-warmed, nutrient-poor water floating on top of the cold, nutrient-rich water. When the winds arrive, the warm water gets pushed away and the deeper water rises to replace it.

This annual upwelling is important because it carries fresh nutrients (natural fertilizers) to the marine algae that live in the sunlit regions. In turn, the marine algae—kelp, for example—provide food for many other animals that live in the Channel Islands area. Scientists have learned how important upwelling is to the Channel Islands by studying how local plant and animal populations have suffered when there was very little upwelling, as happens during **El Niño.**

El Niño is a weather condition that affects the entire Pacific Ocean every 3 to 8 years and lasts for about a year once it starts. In an El Niño year, water temperatures are warmer than normal around the Channel Islands. This means there is a thicker layer of warm, nutrient-poor water over the cold, nutrient-rich water and it does not get pushed away by the wind as easily as in normal years. In severe cases, upwelling is seriously reduced.

What sorts of plants and animals live on and around the Channel Islands?

Underwater forests of giant kelp provide shelter for numerous species of fish, like the colorful garibaldi. Five different species of seals and sea lions come to the island beaches to mate, give birth, and care for their young. Further inland, the islands support many of the same plants and animal species that also live on the mainland of California. For example, the gnarled Torrey pine tree is native both to Santa Rosa Island and the north shore of San Diego. The islands also support **endemic** species, like the island fox, that are entirely unique to the islands.

The garibaldi, the "state marine fish" of California, roams the Channel Islands' extensive kelp forests.

Research *article*

Fact or *Fallacy?*

Every day, thousands of gallons of petroleum oil seep into the ocean near the Channel Islands.

Fact: *Tectonic plate movement has rumpled the sea floor of the Santa Barbara Channel like a bunched-up carpet. Over millions of years, valuable deposits of petroleum oil have collected underneath the sea floor's folds. In some regions off the coast of Santa Barbara, faults have cracked open these underwater oil deposits. In the waters off Santa Barbara's Coal Oil Point, more than 8,000 liters (2,000 gallons) of oil naturally spill into the water every day*

Journal Question

Imagine that you are a ranger at Channel Islands National Park and you've recently moved from a post in the mainland city of Ventura to a remote post on Santa Cruz Island. In what ways would your life and environment remain similar? How would they change?

Vocabulary

California Current *n.* A large "river" of cool, wind-driven water that flows south along the California coast.

Continent *n.* A thickened, elevated region of Earth's crust that is mainly (but not entirely) above sea level.

El Niño *n. or adj.* A time of unusual winds and currents in the Pacific Ocean. In the Channel Islands, El Niño generally causes warmer-than-normal sea surface temperatures and increased rainfall and storm activity.

Endemic *adj.* / **Endemism** *n.* A species is endemic to a particular place if it lives in the wild there but not anywhere else.

Tectonic plates *n.* Enormous, thick sheets of rock that slowly move across Earth's surface. Many tectonic plates extend underneath both continents and the sea floor.

Transform boundary *n.* An edge between two tectonic plates that are primarily sliding alongside each other.

Upwelling *n.* A vertical ocean current that pulls deep, cold ocean water toward the surface. The current is driven by winds that push the warmer surface water away and make room for the deep water.

The Mystery of the Pygmy Mammoth

Focus *questions*

How are the Channel Islands similar to and different from mainland California?

How did the Channel Islands come to be and how did plants and animals populate them?

Materials

For each group

Copy of Master A (pygmy mammoth information)

2 copies of Master B (western half of Santa Barbara Channel model)

2 copies of Master C (eastern half of Santa Barbara Channel model)

Colored pencils

12 sheets of thin craft or floral foam (8½ by 11 inches and about ½ inch thick)

Glue

Felt-tip pens

Scissors

Plastic basin larger than 11 by 17 inches

(*Optional*) Shredded blue construction paper

(*Optional*) Pipe cleaners

(*Optional*) Suction cups

Procedure

1. Read **Master A.** Discuss the following questions with your partners: What exactly is the mystery of the pygmy mammoth? Now read the second part. What is a hypothesis? Why might scientists respond to a mystery with more than one hypothesis?
2. Listen carefully as your teacher explains what bathymetric maps are and how they are read.
3. One student should work on **Master B** and the other on **Master C.**
4. Start by locating the areas of the map that are above sea level. (Sea level is marked by a bold contour line.) Color these areas green.
5. Now locate the lowest contour line on the map. They will be marked "-240 m." This means that they mark lines along which the sea floor is exactly 240 meters below sea level.
6. Using a dark shade of blue, color in all the areas that are deeper than 240 meters. These areas will be marked "< -240 m."
7. Locate the -180 contour in the map. What range of ocean depths can be found between this contour and the one you were looking at in Step 5? Using a lighter shade of blue, color in all the sea floor that is below the -180 contour line but above the -240 contour line.
8. Using progressively lighter shades, continue coloring in the remaining zones of the map: -180 m to -120 m, -120 m to -60 m, and -60 m to 0 m. Ask your teacher to check your map to make sure it has been colored correctly.
9. Cut away the margins (that is, the rectangular outside borders) of the Master you're working on and discard them. Lay the Master on a piece of foam. Trace around its edge, then cut along the traced line. This piece of foam is your base. On it, write down the range of elevations it represents (< -240 meters).
10. Take the Master off the cut-out base. Now cut along the deepest contour line (-240 meters) of the map. Discard the paper representing sea floor deeper than 240 meters. This may divide your map into two pieces of paper.
11. Lay your cut-out map piece(s) on a second piece of foam. Trace the edge of the piece(s) onto this sheet of foam to create a new layer for your model. Cut out the new layer (it may be in more than one piece). On your new layer, write down the range of elevations it represents (-240 meters to -180 meters).
12. Using a spare copy of your Master as a guide, position the "-240 to -180" layer on top of the "< -240" layer. Glue the two layers together.

13. Using Steps 10, 11, and 12 as a guide, attach the remaining layers to the model. You still need the following layers: "-180 to -120 meters," "-120 to -60 meters," "-60 to 0 meters," and "Land: higher than 0 meters." When you're done with the model, let the glue dry overnight.
14. Fit the two models (one from **Master B** and the other from **Master C**) together and place them in the basin. Fill the basin with water (or shredded blue construction paper) until the coastline resembles the present-day coastline of the Santa Barbara Channel. You may need to weight the foam down to keep it from floating.

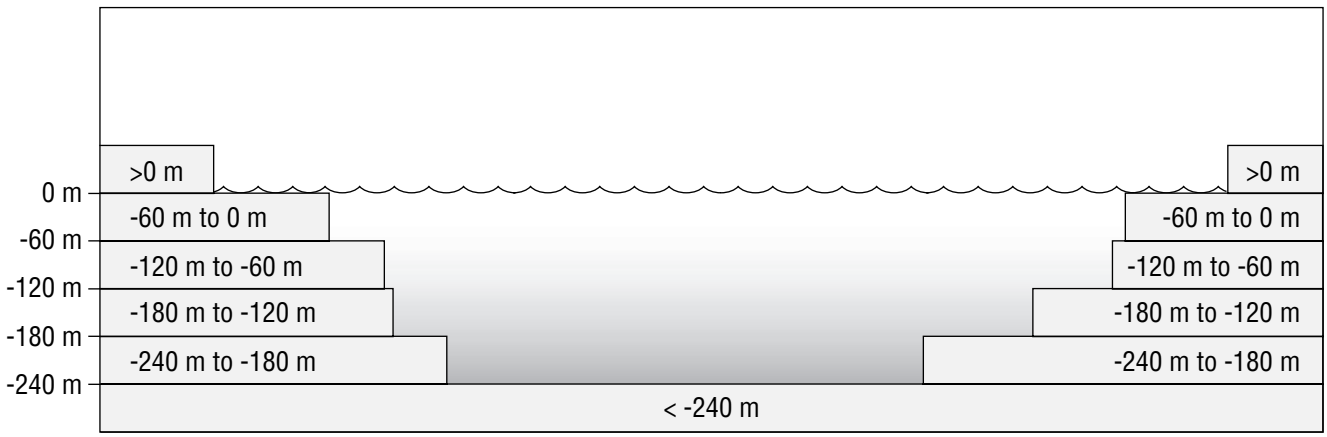
    Another way to keep the model from floating is to run pipe cleaners through the layers and attach suction cups to the pipe cleaners where they stick out underneath the model.
15. Remove water from the basin until a land bridge forms between the mainland and the islands. About how much would the sea level have to fall to join the islands to the mainland? Does the model give you enough information to answer this question precisely?

Conclusion

1. Based on data collected by marine geologists, scientists now know that:
   - The sea level around the Channel Islands dropped approximately 120 meters (400 feet) below current levels during the last ice age, when the Columbian mammoths migrated to the islands.
   - During the last ice age, the bathymetric contours of the Channel Islands area were very similar to the current contours.

Based on this information, did the pygmy mammoths' ancestors have a land bridge to cross over from the mainland? Discuss this question with your partner until you reach a shared conclusion.

2. How do you think a lower sea level might have affected mainland species other than mammoths? (For example, plants, rodents, foxes, and deer.) Discuss this question within your group until you reach a shared conclusion.



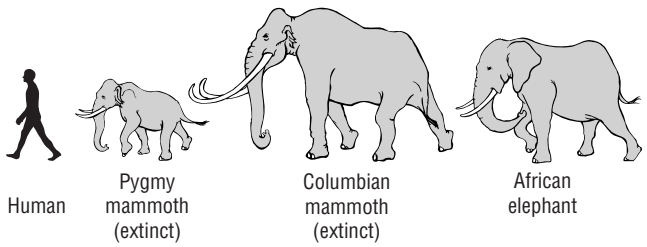
Sample side view of model.

What's a Pygmy Mammoth?

Part 1

For more than a hundred years, scientists working at the Channel Islands have been discovering fossils of a strange creature called the pygmy mammoth. But how can there be a pygmy mammoth? The word "pygmy" means tiny and the word "mammoth" means huge. What's going on?

All the mammoths would seem like big animals by today's standards. For example, the Columbian mammoth of North America stood about 4 meters (14 feet) tall and weighed 4,600 kilograms (10,000 pounds). The Channel Island pygmy mammoths were the descendants of a population of Columbian mammoths that came to the islands roughly 20,000 years ago and was cut off from the general population. The food was scarcer on the islands than it was on the mainland, and the island topography was steeper and rougher. Individual mammoths that happened to be slightly smaller had an advantage over others, because they didn't need to eat as much and they were more agile. Over several thousand years, the average size of the island mammoth population became smaller and, through this process called dwarfism, the pygmy mammoth came to be. From fossils, we know that a pygmy mammoth living on Santa Rosa Island 13,000 years ago stood about 1.7 meters (5.6 feet) tall. Scientists estimate it weighed "just" 900 kilograms (2,000 pounds). It was tiny—for a mammoth!



Ice-Age Mammals

Mammoths were elephant-like mammals that flourished during a time period called the Pleistocene. The Pleistocene began roughly 1,600,000 years ago and ended about 10,000 years ago, at the end of the last great ice age. This time period is best known for its relatively cold global climate and for the large mammals (like mammoths, giant sloths, and saber-toothed tigers) that roamed the world then.

Part 2

The mystery of the pygmy mammoth has to do with how the pygmy mammoths' ancestors first arrived on the Channel Islands. Since they first discovered the mammoth fossils, scientists have suggested two different hypotheses:

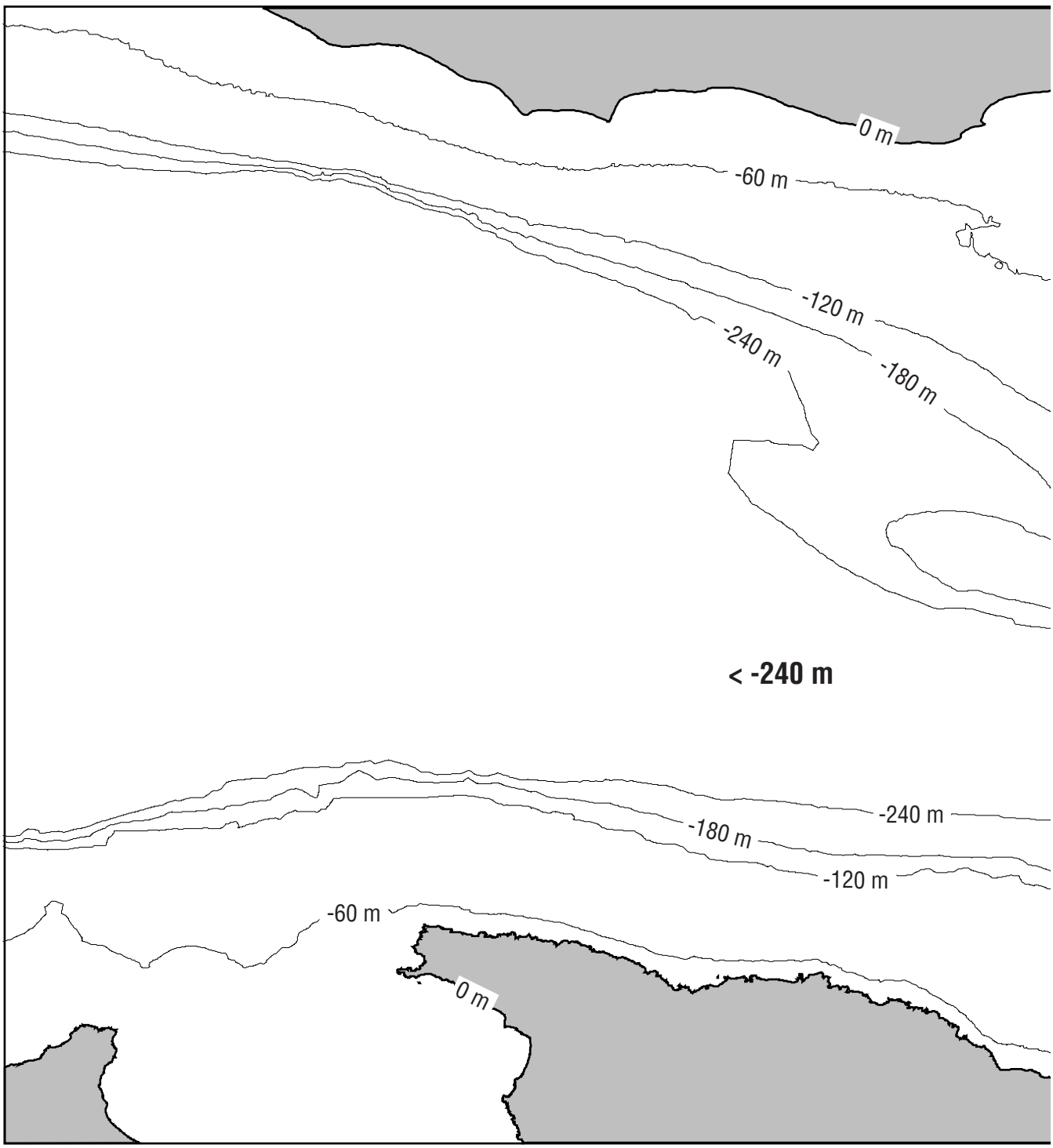
Hypothesis A: During the last ice age of the Pleistocene, so much water was tied up in land-locked ice that the sea levels dropped. This exposed a land bridge between the mainland and the Channel Islands. Mammoths walked across the bridge and were stranded when the sea level rose again.

Hypothesis B: During the last ice age, the sea levels dropped, but not enough to create a land bridge to the mainland. There was still a narrow channel of water separating the islands from the mainland. Since modern-day elephants have been documented swimming distances of up to 48 kilometers (30 miles), the Columbian mammoths may have been able to swim far enough to cross the channel. When the sea level rose again, the size of the channel got to be larger than the distance the mammoths were able to swim.

In this exercise, it will be up to you to make a decision.

Master A

Western Half of Santa Barbara Channel Model



Master B

Eastern Half of Santa Barbara Channel Model

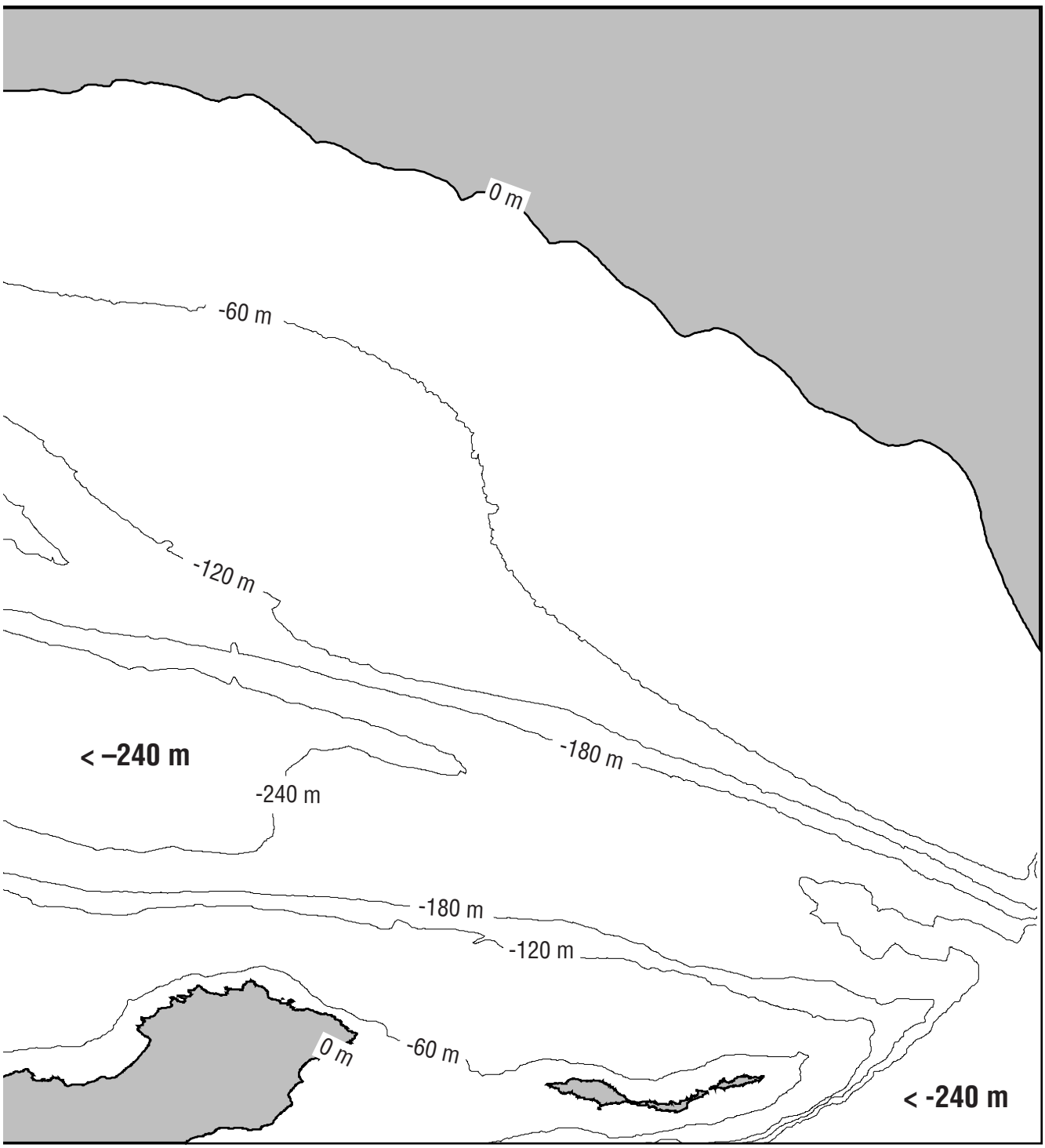


Plate Tectonics Jigsaw

The Channel Islands have played a literally pivotal role in the geologic history of southern California! In this activity, you'll build a moving "jigsaw" model of the plates and blocks that make up this area. You'll use this model to visualize how southern California has changed in the last 18 million years and to explain two sets of experimental observations about the Channel Islands.

Focus *questions*

What is the Western Transverse Ranges Block and how is it part of the geologic history of the Channel Islands?

Materials

For each student

Copy of Master D (base of jigsaw model)

Copy of Master E (pieces for jigsaw model)

Manila folder

Small scissors

Glue

Small hole punch/awl

Thin brass fasteners

Highlighter

Procedure

1. Read the "Making of the Channel Islands" text box on the next page.
2. Cut the manila folder along its crease to create two 8½-inch by 11-inch cardboard sheets.
3. Thoroughly glue **Master D** to one cardboard sheet and **Master E** to the other.
4. Cut all eight pieces out of **Master E:** three pieces shaped like popsicle sticks, one piece labeled "North American Plate," one piece labeled "Baja California," one piece labeled "Pacific Plate," and two pieces labeled "Trans. R." (Note: "Trans. R." stands for "Transverse Ranges Block." The Transverse Ranges Block is represented as two pieces to make the model work better.) The bold initials on these pieces are short for three cities in southern California: Santa Barbara, Los Angeles, and San Diego.
5. Carefully punch small holes where labeled (1a, 1b, etc.) on **Master D** and the **Master E** pieces.
6. Each hole is labeled with a letter and a number. You'll join only holes with the same number.
7. Use brass fasteners to connect the pieces in alphabetical order, as follows. (Insert each brass fastener from the top; once you've inserted the fastener through each piece in the stack, open it and smooth its prongs out.)
   - 1a on 1b on 1c.
   - 2a on 2b on 2c on 2d.
   - 3a on 3b on 3c. (Make sure that 4b pokes out the bottom left of the "Baja California" piece, while 5b pokes out the top right.)
   - Attach 4a to 4b and bend the legs out.
8. Tape or glue the tabs on the "North American Plate" piece to the speckled spots on the base sheet so that features on the two precisely line up. This should leave two slots between the "North American Plate" piece and the base sheet. Feed the two free lever arms (the ones marked 6b and 5b) into the fronts of the slots, and then:
   - Attach 5a to 5b to 5c with a brass fastener and bend the prongs out.
   - Attach 6a to 6b to 6c with a brass fastener and bend the prongs out. Check to see that the edges of the "Baja California" piece ended up on top of the edges of the "Pacific Plate" piece.
9. Line up the Pacific Plate so that the number 18 (printed on the base sheet) appears in the notch. This shows the way that the plates and blocks of southern California were lined up 18 million years ago.
10. For the last 18 million years, the Pacific Plate has been moving to the northwest. 18 million years ago, the area of land now including Los Angeles, San Diego, and Baja California was attached to

the North American plate. Model this by holding Baja California down with your thumb while moving the Pacific Plate from 18 to 12 to 6 million years (Ma) ago. What happens to the Transverse Ranges Block during this movement?

11. Around 6 million years ago, the area marked "Baja California" broke off of the North American Plate and joined the Pacific Plate. Let go of Baja California and keep pulling the Pacific Plate northwest. What happens to the Transverse Ranges Block? What happens between Baja California and mainland Mexico?

Conclusion

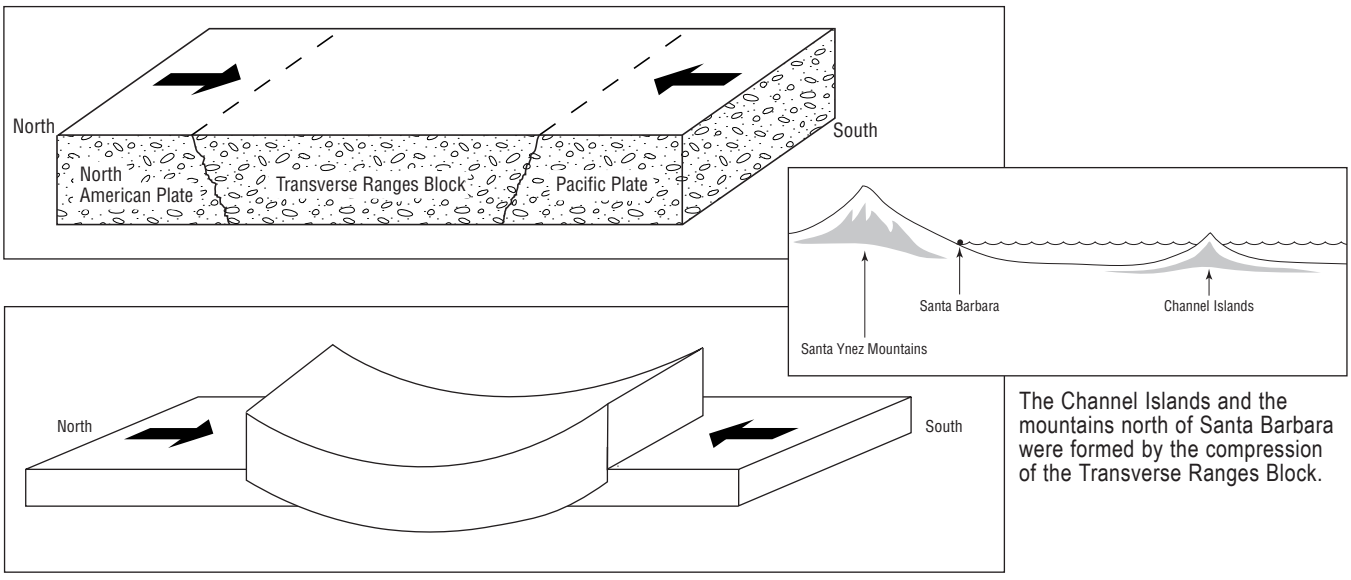
Use your model to think about the following experimental observations. With a few written sentences, explain each of the observations.

1. When rocks form from cooling lava, tiny magnetic particles in the lava act like compass needles and line up along Earth's north-south magnetic axis. With cooling, the particles are "frozen in place" inside the rock. On the southern Channel Islands, magnetized rock particles point toward the magnetic north pole. On the northern Channel Islands, though, they point nearly east. Why is this?
2. On San Miguel and Santa Rosa, there are large deposits of a rock called conglomerate. The Channel Islands conglomerate contains rounded pebbles and gravel particles very similar to those found in old river deposits around San Diego. Why is this?

The Making of the Channel Islands

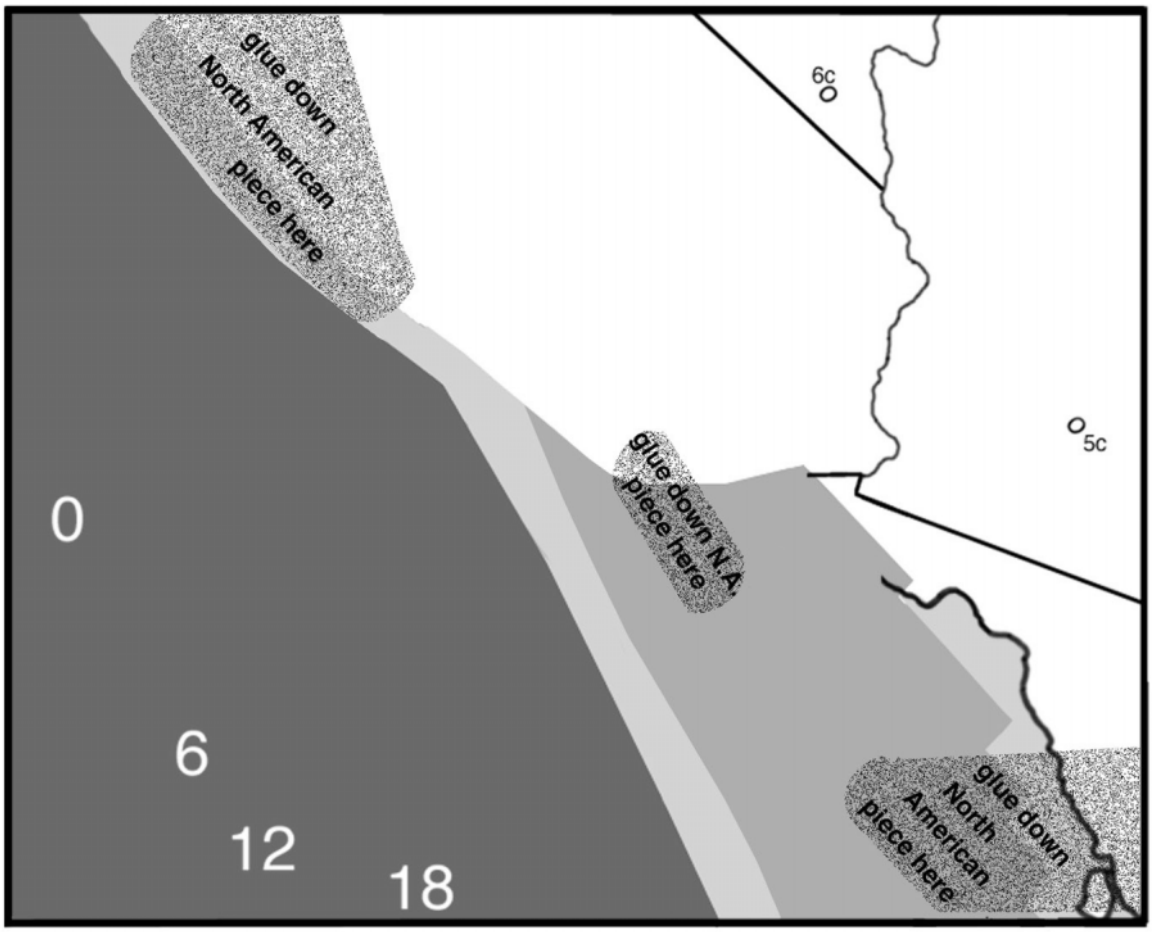
In between the Pacific and the North American Plates, there are a few smaller blocks of Earth's crust that are getting broken up and pushed along. The Channel Islands, the Santa Barbara Basin, and the mountains north of Santa Barbara are all on a single splinter of the Pacific Plate called the Transverse Ranges Block (labeled in **Master E**). The Transverse Ranges Block is currently wedged between the main Pacific Plate and the North American Plate, and it is being slowly squeezed between them. As Dr. Atwater describes it, the block is like a log that was once floating parallel to the edge of a river (the main Pacific Plate). Then the downstream end of the block jammed into the riverbank (the North American Plate). The force of the Pacific Plate has flipped the block around and pushed it northward. This explains why the coast of California makes a sharp turn around Point Conception—the Point is where the Transverse Ranges Block sticks out into the Pacific Plate.

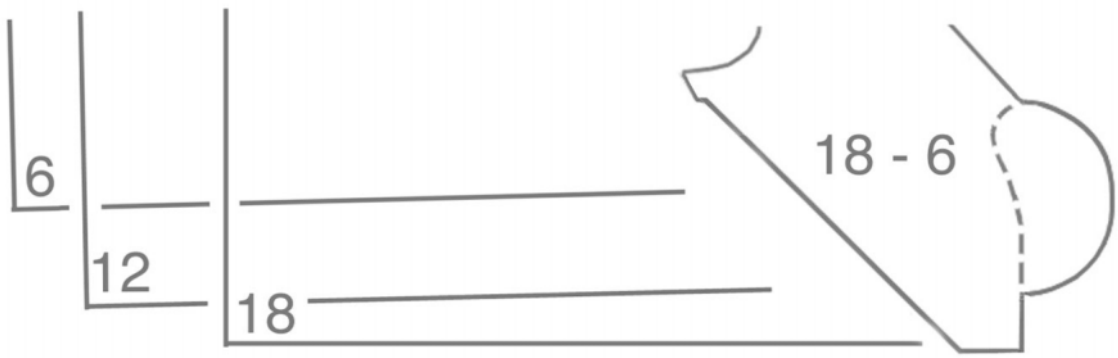
The intense pressure of being squeezed between the Pacific and North American Plates lifted the southern rim of the Transverse Ranges Block, forming the Channel Islands. The pressure also wrinkled up the middle of the Block and lifted the Block's northern rim, forming the Santa Ynez Mountains, north of Santa Barbara.



The Channel Islands and the mountains north of Santa Barbara were formed by the compression of the Transverse Ranges Block.

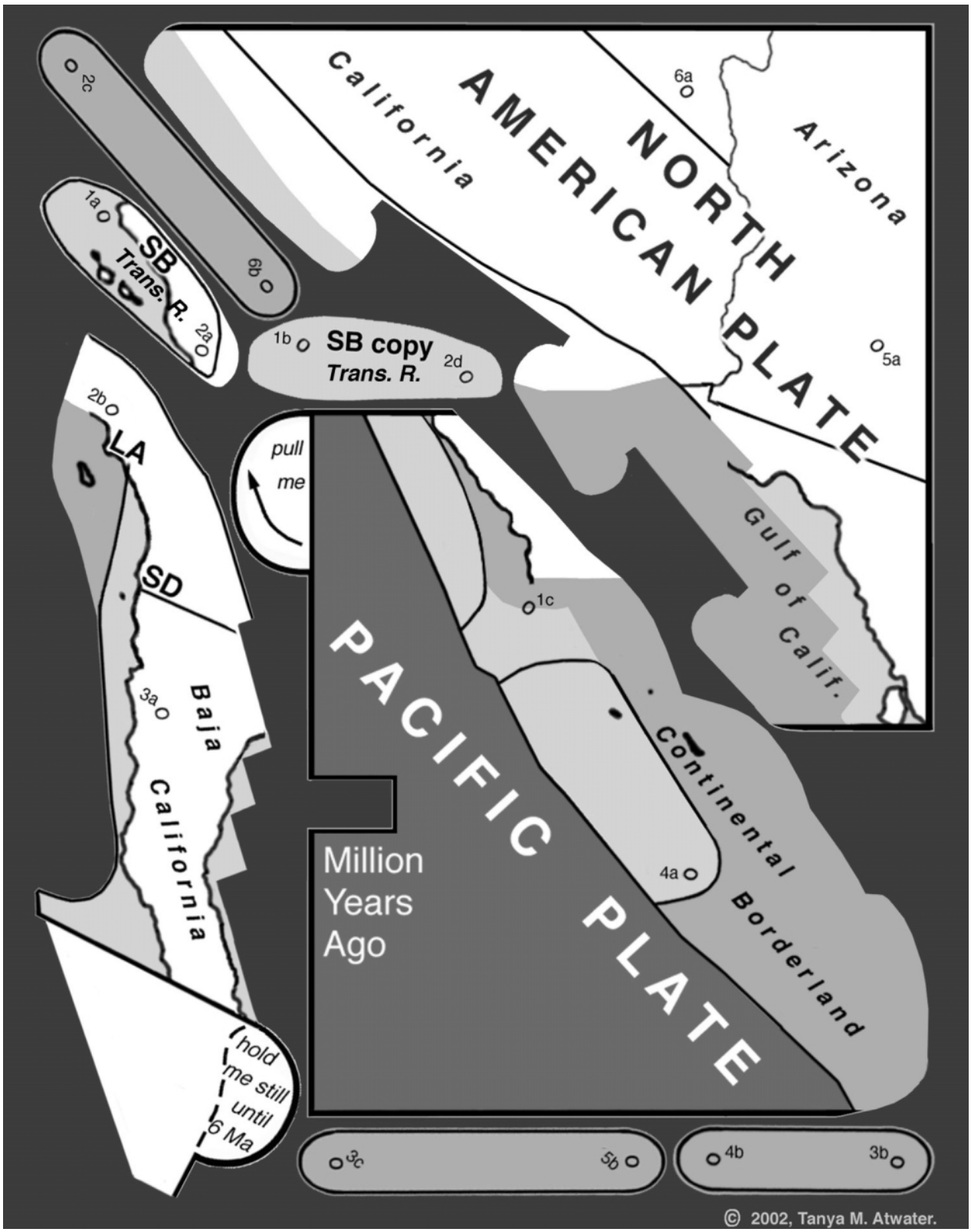
Base of Jigsaw Model





Master D

Pieces for Jigsaw Model



Surveying the Channel Islands

In this exercise, you will compare all the Channel Islands—the northern ones off the coast of Santa Barbara and the southern ones off the coast between Los Angeles and San Diego. You'll use maps to estimate two kinds of geographic information about each island: size and remoteness. Think about how this survey helps to explain the ecological differences between the islands.

Focus *questions*

What factors influence the number of plant and animal species living on an island?

Exercise 1.3

Materials *For each student*

Copy of Master F (survey vocabulary)

Copy of Master G (size comparison map, part I)

Copy of Master H (size comparison map, part II)

"Quad-ruled" graph paper (4 squares to an inch)

Ruler

Copy of JASON XIV Atlas Map 2

Procedure

1. Read and discuss **Master F.** Using **Masters G** and **H,** trace the outlines of the Channel Islands onto graph paper.
2. Using the legend on **Masters G** and **H,** determine how much area each square of your graph paper represents.
3. By counting the number of squares inside the island outlines you traced, estimate the area of each island. As you count, record each island's area on the chart below.
4. With a partner, estimate the area of the county you live in. Then pick one of the islands. How does your county's area compare to the area of the island you chose?
5. Using Map 2 in the JASON Atlas and a ruler, measure (in kilometers) the *shortest possible distance* to the mainland from each of the islands. Record each value in the chart below.
6. Can you devise any patterns or relationships to describe the data in your completed chart? For example, islands with larger area tend to have more species of native plants. Can you come up with any other patterns? Do these patterns have exceptions?

Conclusion

1. What do you think are the underlying explanations for the rules you have come up with?
2. Find out how accurate your area estimates were. Research the "official" areas of each of the Channel Islands and compare these with your estimates. How do you think you could improve the accuracy of your estimation process?

For Further Exploration

Mapping an area's boundaries and determining its area is called surveying. Can you think of any practical situations in which surveying is important? For a research project, find out more about the history of surveying. (For a starter, did you know that George Washington began his career as a professional surveyor?)

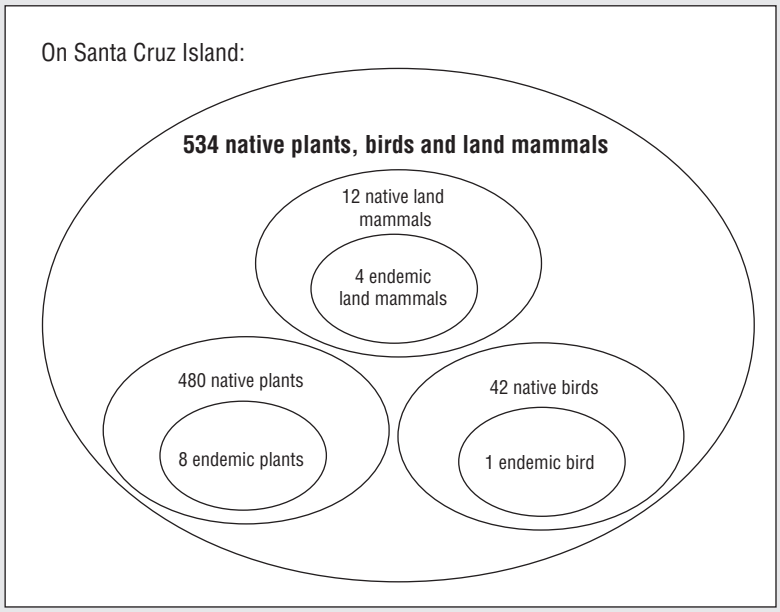
Number of different species that are either native or endemic to the Channel Islands.

Island	Area (km^2)	Shortest Distance to Mainland (km)	Number of Species of:						
			Total Native Plants, Birds, and Mammals	Native Plants	Endemic Plants	Native Birds	Endemic Birds	Native Land Mammals	Endemic Land Mammals
Santa Barbara			103	88	2	13	0	2	1
Anacapa			213	190	1	21	0	2	1
San Miguel			216	198	0	15	1	3	2
San Nicolas			154	139	2	13	0	2	2
San Clemente			302	272	17	24	2	6	2
Santa Catalina			463	421	7	33	0	9	4
Santa Rosa			416	387	4	25	0	4	3
Santa Cruz			534	480	8	42	1	12	4

Survey Vocabulary

Endemic and Native

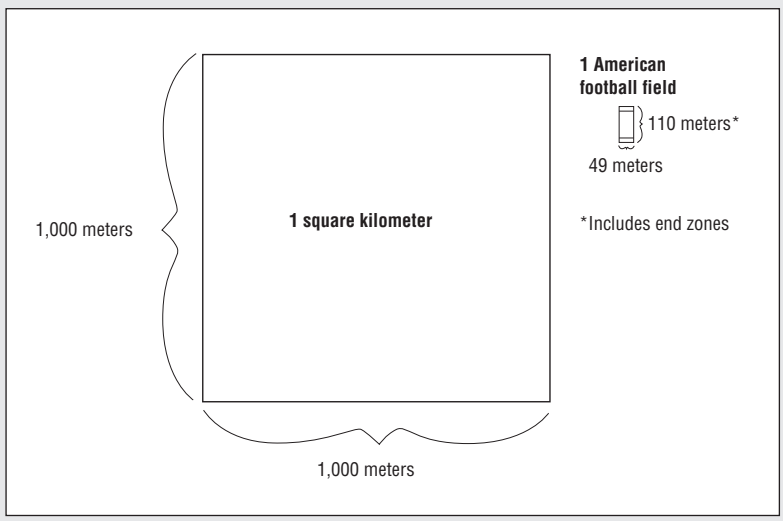
Remember: a species that is *native* to the Channel Islands may also be found on the mainland, but it migrated there without human intervention. A species that is *endemic* to the Channel Islands may be found on more than one of the islands but is not found anywhere else in the world. All endemic species are also native, but many native species are not endemic. In the chart on the previous page, the tally of native species includes both endemic and non-endemic species.



Native and endemic species on Santa Cruz Island.

What's a Square Kilometer?

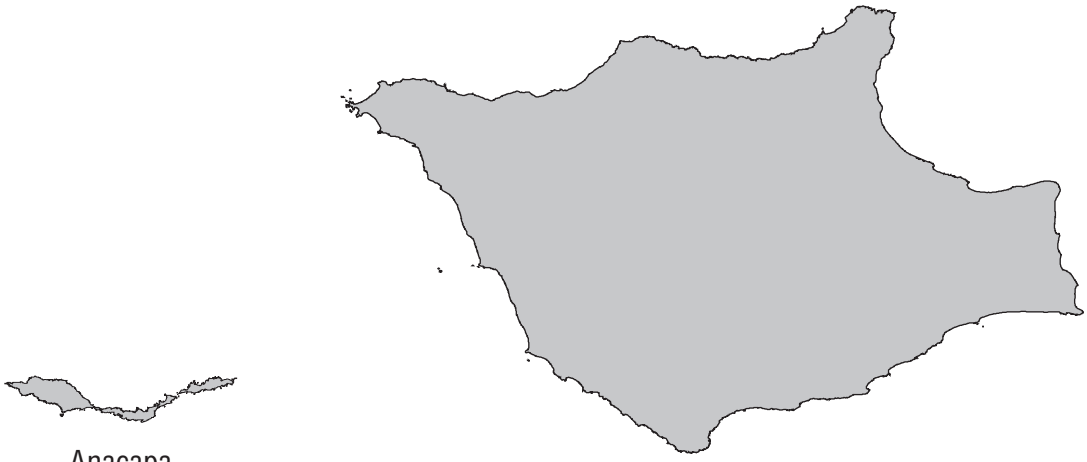
A square kilometer is the area of a square that is 1,000 meters on each side. That means 1 square kilometer is 1,000 meters × 1,000 meters, or 1,000,000 square meters! For the sake of comparison, a football field has an approximate area of 110 meters × 49 meters, making it 5,390 square meters in area.

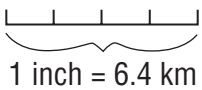


A square kilometer, with an American football field for comparison.

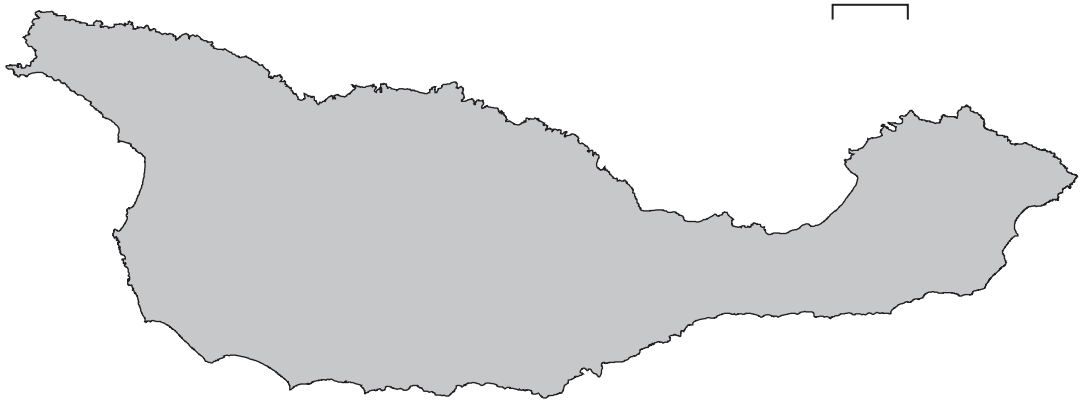
Master F

Size Comparison Map of the Channel Islands, Part I





1 centimeter = 2.5 km



Master G

Size Comparison Map of the Channel Islands, Part II

SHOW WHAT YOU KNOW!

Adopt An Island

Self assessment

Skills: Organizing Information, Communicating

It's your job to "adopt" one of the Channel Islands by learning as much as you can about it and then delivering a presentation to your classmates about what makes your island unique.

Your Challenge

Choose one of the Channel Islands (San Miguel, Santa Cruz, Anacapa, Santa Rosa, Santa Barbara, Santa Catalina, San Clemente, or San Nicolas).

Gather evidence that shows what your island is like. Be on the lookout for ways that your island is similar to and different from its neighbors. Look for interesting information that you may have already recorded about your island in your notes, JASON Journal, or class projects. Look on the Internet for new information about your island.

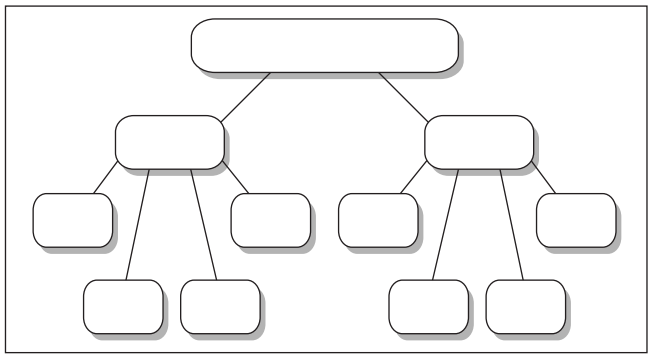
Words, Words, Words

Think about and use as many of these vocabulary words as you can: *California Current, upwelling, El Niño, endemic, native, non-native, human impact.*

Helpful Hints

Make a concept map to exhibit your information.

1. Fill in the largest shape of the concept map with the name of the island.
2. Decide what categories your information belongs in. For example, you could divide your information into "geology, ecology, and geography." Another, simpler way of organizing your information might be "living and nonliving." Be creative in deciding how to organize your information!
3. Do you need to add more shapes to your concept map to organize your information?



Concept map.

Materials

JASON Atlas Maps 2, 3, and 6

Paper, colored pencils, ruler

Access to research resources

Personal JASON Journal, notes, or results of class projects

Assess Your Work

Use this chart to assess your own work.

Skills and Steps	Yes	No	Not Sure
Identified what makes my island unique.			
Identified what makes my island similar to other Channel Islands.			
Used a concept map to organize my thoughts.			

Conclusion

What have you learned about how your island relates to neighboring islands and the mainland?

TEACHER LINKS 1

Mathematics Links

Plot a Bathymetric Map. Divide your class into groups. Have each group build a box full of "unmapped ocean" by gluing various oddly shaped objects to the bottom of a shoebox, then taping on the lid and carefully poking an evenly spaced 3-by-6 grid of pencil-sized holes in the lid. Have the groups exchange boxes. Then tell each group to measure the distance between the lid of their shoebox (the ocean surface) and the bottom of the shoebox (the ocean floor) at each hole. They can do this by probing (straight down) with a skewer and marking the depth on the skewer. Have each group transfer their depth readings to graph paper and draw a bathymetric map of the bottom of the shoebox. Now tell them to remove the shoebox lids and compare their maps with the shoebox contents.

Language Arts Links

Formulating Research Questions. Most explorers and scientists start with a question: What lives on that island? What lived there thousands of years ago? In chat sessions on Team JASON Online and during the live broadcast, students will have the chance to ask host researchers about their work. Have them write some questions for the researchers in their JASON Journals. Encourage students to (1) ask questions that let researchers expand on a topic, rather than "yes" or "no" questions; and (2) ask informed questions that show researchers they've already learned something about a topic and are eager to know more!

Arts Links

Paint a Mural. Have your class paint a mural of one of the Channel Islands, showing scenes from its natural history. They should design and arrange these scenes in a way that conveys a sense of *chronological narrative*. The mural should tell a story about change over time. It should include elements having to do with changes in Earth's crust, ocean currents, the movement of plants and animals to the islands, and the evolution of plant and animal populations.

Novel Links

20,000 Leagues under the Sea. How accurate are the *Nautilus's* observations of underwater volcanic effects and the rise and fall of islands? Compare Captain Nemo's thoughts with a scientist's view of how the Channel Islands formed.

Island of the Blue Dolphins. Find San Nicolas Island on an Atlas map. From the novel, draw a map of the island and its features. Where would you place it in relation to your 3-D model?

***The Voyage of the* Frog.** Learn more about the currents off the California coast. Debate whether currents could have carried the *Frog* further south in the storm than David thought.

The Case of the Missing Cutthroats. Find New York City and Jackson Hole, Wyoming, on a physical map. How do their location and geologic features affect their weather, human use, and animal life?

Zia. Find the settings of *Zia* on the Atlas map of the Channel Islands. List the features of each area (cliffs, caves, etc.) and consider how elements of the research story (ocean currents, climate, species) might have been a factor in the formation of each.

Web Links

pubs.usgs.gov/publications/text/dynamic.html Online book with information on plate tectonics and oil seeps.

www.pmel.noaa.gov/tao/elnino/el-nino-story.html NOAA page with information and images about El Niño.

www.tarpits.org/exhibits/fossils/ Page on the La Brea Tar Pits; has information on mammoths and the Pleistocene.

See Team JASON Online for more Web links.

TEACHER LINKS 1

Technology Links

Go Deeper Online. Have students visit the Team JASON Online Geology and Geography Story Page for streaming versions of the JASON XIV videos and a collection of links to further information on Research Story 1. Visit the Earth Systems—Tectonics and Vulcanism Digital Lab for more on plate tectonics

Surveying Technology. Surveying techniques have advanced through the years. Today, some surveyors use advanced technologies like the Global Positioning System (GPS) and geographic information systems (GIS).

Consider having your students survey your school grounds or a field study location using a GPS receiver. To map out the survey, students can use either pencil and paper or a GIS program on a computer. Have them record building dimensions and locations of other landmarks on the school property; in the field, have them record locations of endemic or unique species. Consider comparing the map you prepare to any the school has on file. If you are looking for another use for surveying technology, consider having students use graphics or GIS software to calculate/estimate island areas in Exercise 1.3.

Teacher Preparation 1.1

The Mystery of the Pygmy Mammoth

Time Required

1½ hours (two 45-minute periods)

Complexity

High

Additional Preparation

1. Be prepared to explain to your students how to read a bathymetric map. A bathymetric map works on the same basic principle as a topographic map: a contour line represents a single elevation and the area between two contour lines represents a range of elevations. In **Masters B** and **C,** each contour line marks 60 meters of elevation change. While topographic maps represent the elevation of dry land, bathymetric maps represent the depth of sea floor covered by water.
2. You can obtain thin foam sheets at a local craft store (or try recycling foam from leftover packaging). Before buying a lot of sheets, be sure to test the foam out to make sure it can be cut and glued easily.

Answers to Questions

Procedure questions

1. The underlying "mystery" is how the pygmy mammoth's ancestors (full-size Columbian mammoths) got to the island. When insufficient data are available about a particular topic and/or the interpretation of those data is unclear, scientists may have legitimate differences of opinion about whether a hypothesis is correct. Explain to the students that scientists decide between competing hypotheses by gathering additional data and, if necessary, building a new consensus about how those data should be interpreted.

7. The layer should be labeled "-240 to -180 meters."

15. Sea level would have to drop somewhere between 180 and 240 meters. You would need a model with smaller contour intervals to answer the question more precisely.

Conclusion questions

1. The sea level did not fall enough to create a land bridge between the Channel Islands and the mainland, so the mammoths must have swum across. The lower sea level, however, did decrease the distance the mammoths had to swim.
2. A lower sea level might have made it easier for plants and animals other than mammoths to colonize the islands, since it decreased the distance of open water that had to be crossed. The plants and animals would still have had to drift, fly, swim, or "raft" their way to the Channel Islands.

Adaptations

For elementary school students

Younger students may need more teacher assistance with reading and cutting the map contours. Try enlarging the Masters to make them easier to work with.

For high school students

Have older students theorize about why the island mammoth population evolved to become a different species from the mainland population. This may involve some research into evolutionary theory and the meaning of the term "species." Students might also consider the genetic implications of a population descended from a very small number of founding individuals (this is known as the "founder effect").

Teacher Preparation 1.2

Plate Tectonics Jigsaw

Time Required

1½ hours (two 45-minute periods)

Complexity

Medium

Additional Preparation

As an alternative to having students glue the Masters onto manila folders, try photocopying them directly onto cardstock or heavy paper.

Teacher Take Note

The directions for building the plate tectonics model need to be followed precisely. You may want to build a working model in advance so that students can see what they are trying to build. See also the geologic history section of the JASON XIV video, where this puzzle is used.

Answers to Questions

Procedure questions

10. Students should see the Transverse Ranges Block pivot from a primarily north/south orientation to a primarily east/west orientation.
11. Students should see that the Pacific Plate is pushing the Transverse Ranges Block northward, into the North American Plate. Students should see that a new little ocean, the Gulf of California, is being formed as the Pacific Plate pulls Baja California away from mainland Mexico.

Conclusion questions

1. The magnetic particles point in the direction that was north when they formed from lava. Since then, they have been physically rotated about 90 degrees clockwise (from north to east). Students can model this by drawing north-pointing arrows on the Transverse Ranges Block in the "18 million years ago" setting and then moving the model into the present-day configuration.
2. 18 million years ago, the Channel Islands were located just west of the area that is now San Diego. Rivers carried sediment and gravel downstream from the San Diego area to the Channel Islands area.

Adaptations

For elementary school students

Younger students may have trouble with the careful assembly required to make their own plate tectonics models. Rather than having them build models for themselves, pre-assemble several models and have them complete the rest of the activity in small groups.

Teacher Preparation 1.3

Surveying the Channel Islands


Time Required

1½ hours (two 45-minute periods)

Complexity

Medium

Additional Preparation

In the graph paper area estimation exercise, some students may ask what to do about squares that are partly inside the island border and partly outside the

island border. Suggest as a rule of thumb that students count just those squares that appear to be filled in more than halfway. Students might even try keeping track of fractions of filled-in squares.

If you plan to have your students compare the size of the Channel Islands to the size of your home county, obtain a local map of your county that provides scale information. For a directory of information about U.S. counties, visit **www.naco.org/counties.**

Answers to Questions

Procedure questions

2. Each square of quad-ruled graph paper is a quarter inch long and wide. Since 1 inch = 6.4 kilometers, ¼ inch represents 6.4 km ÷ 4, or 1.6 km. Each square of the graph paper represents an area of 1.6 km × 1.6 km, or 2.56 km.
3. Here are the official estimates of the islands' areas (in square kilometers): Santa Barbara (2.6), Anacapa (2.9), San Miguel (37), San Nicolas (58), San Clemente (145), Santa Catalina (194), Santa Rosa (217), Santa Cruz (249). Students' estimates may vary somewhat from these values.
4. Answers will vary, but the typical county will be one to two orders of magnitude larger than one of the Channel Islands.
5. Here are the official estimates of the islands' shortest distances to the mainland (in kilometers): Santa Barbara (61), Anacapa (20), San Miguel (42), San Nicolas (98), San Clemente (79), Santa Catalina (32), Santa Rosa (44), Santa Cruz (30). Students' estimates may vary somewhat from these values.
6. The two important relationships that the students should come up with are the following:
   - There are generally more native species of plants, birds, and mammals on bigger islands.
   - There are generally more native species of plants, birds, and mammals on islands that are closer to the mainland. These relationships also hold (but less well) for the numbers of endemic species.

Conclusion questions

1. The rate of extinction is influenced by the size of the island. A larger island has the space and resources to allow a larger number of different species to coexist in the ecosystem. The rate of new species immigration is influenced by an island's distance from the mainland. On a less remote island, there is a greater chance of random events (storms, floating debris, etc.) bringing new kinds of mainland organisms.

   Even though different species are continually immigrating and going extinct, the total number of species on an island tends to remain fairly constant, barring major disruptions like a change in climate.
2. See Step 3 of the Procedure section. Some ways to improve the accuracy of the estimation process would be: obtaining larger or higher-resolution maps of the islands, using smaller-ruled graph paper, and analyzing the maps with GIS software on a computer rather than with graph paper.

Adaptations

For elementary school students

With younger students, you may wish to limit the area-estimation exercise to just calculating the area of the classroom (or an even smaller area). Then provide them with the area and remoteness data for the Channel Islands and have them look for relationships with the ecological data.

For high school students

1. Have the students graph the relationships between island area/remoteness and number of species using scatter plots. Discuss the mathematical concept of correlation and have them calculate the correlation coefficients for the relationships.
2. Set up a "field expedition" contest with the students to see who can most accurately estimate the area of some large plot of land that has already been precisely surveyed (like the school property). You might even try using GPS technology and mapping software on a computer.