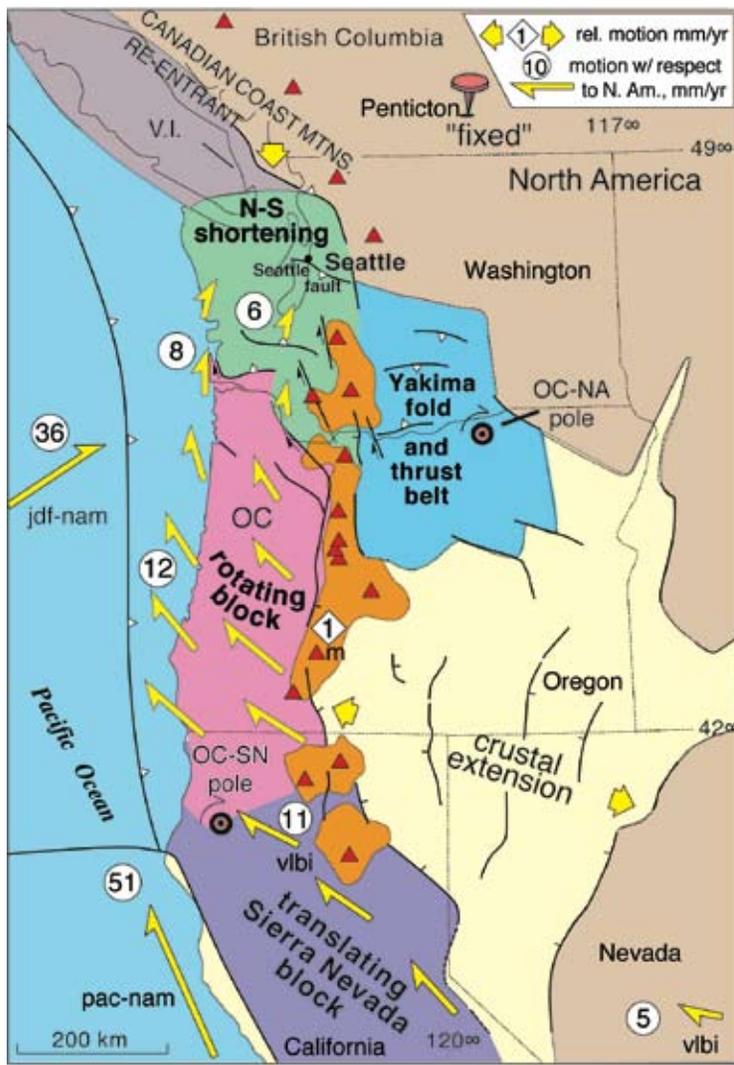


Activity–Pacific Northwest Tectonic Block Model



Wells and Simpson, 2001;
after Wells et al., 1998

The Cascadia tectonic margin is caught between several tectonic forces, during the relentless motions of the giant Pacific Plate, the smaller subducting Juan de Fuca Plate, and the North American Plate.

The hands-on model that you received was derived from GPS data collected for decades to show the movement of microplates of the Pacific Northwest, and where they are headed under the current stress regime over the next 8 million years.

Science Standards (NGSS; pg. 287)

- From Molecules to Organisms—Structures and Processes: MS-LS1-8
- Motion and Stability—Forces and Interactions: MS-PS2-2
- Energy: MS-PS3-2, HS-PS3-2, MS-PS3-5,
- Waves and Their Applications in Technologies for Information Transfer: MS-PS4-2, MS-PS4-3, HS-PS4-5
- Earth’s Place in the Universe: HS-ESS1-5
- Earth’s Systems: HS-ESS2-1, MS-ESS2-2, HS-ESS2-2, MS-ESS2-3, HS-ESS2-3
- Earth and Human Activity: HS-ESS3-1, MS-ESS3-2

Additional Resources on this DVD relevant to the PNW Block Model

ANIMATION—in the folder: **4. ACTIVITIES Cascadia Earthquakes & Tsunamis**

 > PNW Tectonic Block Model

 > Resources

 > 1. PacNW-model-8my-Narrated.mov

Pacific Northwest Tectonic Block Model*

Teacher background

This activity has students use a "hands on" tectonic block model of the Pacific Northwest. The model consists of a tectonic map with moveable pieces that show the northward migration, clockwise rotation, and deformation of crustal blocks along the Cascadia convergent margin of the Northwestern US. The model is derived from the published tectonic models of Wells et al. (1998) and Wells and Simpson (2001), and it is consistent with recent GPS findings that indicate that clockwise rotation is continuing today (McCaffrey et al, 2000). **It shows how western North America is breaking up into smaller crustal blocks due to shear by the northward-moving Pacific plate and by Basin and Range extension inboard of the moving crustal blocks.**

The model links clockwise rotation of the Oregon Coast Range (pink) to northwest motion of the Sierra Nevada block (purple) by a "hinge" in Klamath Mountains, and it predicts the long-term velocity of coastal blocks with respect to stable North America (yellow arrows). The southern Cascade volcanic arc (red triangles) erupts along the trailing edge of Oregon block in a region of crustal extension. Orange areas, representing young volcanic rocks erupted in the last 2 million years, are more voluminous south of Mt. Rainier, when compared to the northern arc, where block motion compresses the volcanic arc.

Northward motion of the Oregon coastal block squeezes western Washington (green) against Canadian Coast Mountains restraining bend, causing N-S compression, uplift, thrust faulting, and earthquakes. Some of the earthquakes and faults in Puget Sound, such as along the Seattle fault, are caused by the northward migration of coastal blocks. East-west faults are mostly thrust faults that absorb N-S compression and crustal shortening as the region is squeezed against the Canadian Coast Mountains buttress by northward-moving coastal blocks.

Not shown in the model, but revealed in the GPS data (McCaffrey et al, 2000; Miller et al, 2001), is the shorter-term eastward motion of the coast due to build up of elastic strain above the subducting Juan de Fuca plate. This is also an important part of the overall picture of Northwest earthquake hazards. Much of this eastward compression will be released in the next subduction earthquake, while the northward shortening will continue to be accommodated by faulting and earthquakes in the upper plate.

Guiding Questions:

- How does this model differ from the typical plate boundary model for the PNW?
- How does this model help to delineate the two major types of earthquakes that occur in the PNW?

Goals:

- Recognize the major tectonic blocks of the PNW
- Understand the movement of PNW blocks relative to each other and the North American Plate
- Distinguish between the subduction zone earthquakes and crustal earthquakes

Materials:

- Pacific Northwest Plate Tectonic Model Poster
- Pacific Northwest Plate Tectonic Model page for student worksheet (next page)
- Student handouts
- Colored pencils/crayons

Answer sheets follow the Student handouts.

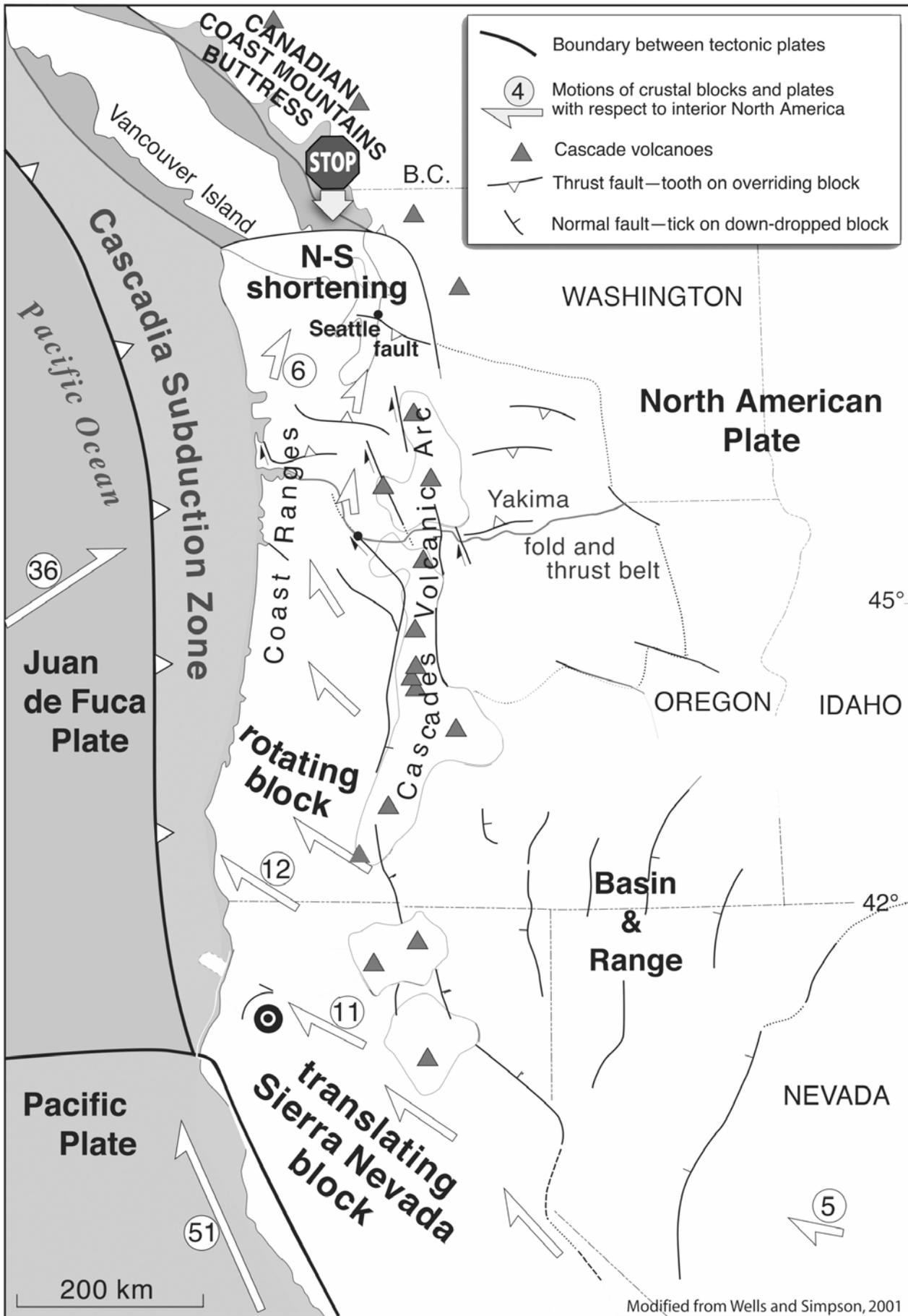
Oregon State Science Standards (8th grade): Earth and Space Science

CCG: The Dynamic Earth: Understand changes occurring within the lithosphere, hydrosphere, and atmosphere of the Earth.

- *SC.08.ES.03 Describe the Earth's structure and how it changes over time.*
- *SC.08.ES.03.02 Identify the processes that result in different kinds of landforms.*
- *SC.08.ES.03.04 Give examples of landform changes that occur at different rates.*
- *SC.08.ES.03.05 Describe the evidence for and the development of the theory of plate tectonics.*
- *SC.08.ES.03.06 Explain the rock cycle in terms of constructive (crustal deformation, volcanic eruption, and sediment deposition) and destructive (weathering and erosion) forces in land formation.*

*Activity and worksheets by Chris Hedeem, Oregon City High School, Oregon City OR

Pacific Northwest Tectonic Block Model



Instructions:

Using this handout and the map provided, use the Pacific Northwest Tectonic Block Model to gain a better understanding of how plate tectonics influences Pacific Northwest geology.

Part A: The Plates

Place a mark in the box after you have completed each step:

- Circle the names of the three major tectonic plates labeled on the map.
- 1. Which two plates are interacting at the Cascadia Subduction zone?
- 2. Which plate is being subducted? How do you know?
- 3. How does this subduction lead to the formation of the Cascades Volcanic Arc?
- 4. What types of earthquakes does the Cascadia subduction zone produce?
 - a. Are they typically large earthquakes?
 - b. When was the most recent large earthquake on the Cascadia subduction zone?
 - c. What other geologic event can occur with large subduction zone earthquakes?

Part B: The Crustal Blocks

Using the model, locate the three major tectonic blocks on the western edge of the North American Plate.

<input type="checkbox"/> Identify the Sierra-Nevada block on your map. Lightly shade it in purple .
<input type="checkbox"/> Color in the arrows on the Sierra-Nevada block in yellow .
<input type="checkbox"/> In which compass direction does it move with respect to interior North America? (Circle your choice) North South Northeast Northwest
<input type="checkbox"/> What is the approximate rate of movement of this block relative to the North American Plate? _____ (mm/yr)

<input type="checkbox"/> Identify the Coast Range block of Oregon on your map. Lightly shade it pink.
<input type="checkbox"/> Color in the arrows in yellow.
<input type="checkbox"/> In which compass direction does it move with respect to interior North America? (Circle your choice) North South Northeast Northwest
<input type="checkbox"/> What is the approximate rate of movement of this block relative to the North American Plate? _____ (mm/yr)
<input type="checkbox"/> Identify the Western Washington block on your map. Lightly shade it in green.

- Color in the arrows in yellow.
- In which compass direction does it move with respect to interior North America? (Circle your choice)
- North South Northeast Northwest**
- What is the approximate rate of movement of this block relative to the North American Plate?
_____ (mm/yr)

To answer the following questions, it will be helpful to use the model to move the crustal blocks. You'll want to pay particular attention to how the plates interact with each other when moved.

1. Which crustal block is moving the most to the west?
2. Which crustal block is moving the most to the north?

Notice that the Sierra Nevada Block is moving more than the Western Washington Block is moving. (You can tell this by the length of the arrows that you colored yellow).

3. What geologic feature prevents the Western Washington block from moving any farther to the north?
4. What is pushing the Western Washington block to the north?
5. If the Western Washington block cannot go any farther to the north but is still being pushed from the south, how is the crust in Western Washington going to respond?
6. How is the crustal block in Oregon going to respond to being pushed from the south, but stopped by the Western Washington block?
7. What types of features (**mountains, folds, faults**) are going to be formed as a result of these movements? Where are these features going to be located? Are they already present? **Color these features red on the map. (Hint: Look at the key in the upper right hand corner!)**
8. You just colored in the major faults in the Seattle and Portland areas. What types of faults are they?
9. Describe the types of earthquakes they are likely to produce. (Deep and/or shallow, large and/or small, frequent and/or rare, etc.)

Identify the **Cascades Volcanic Arc** on your map using the larger model. Color in the volcanoes in **red** and the surrounding volcanic rocks in **orange**. *IMPORTANT: Notice that the Cascade Volcanoes in northern Washington and southern Canada are not surrounded by orange volcanic rocks.*

10. The Cascades Volcanic Arc lies to which side of the three crustal blocks you have already identified:
(Circle your choice)

North South East West

11. Where does the lava that forms these volcanoes come from?

Notice that the volcanoes start in northern California and extend north to central Washington.

12. Suggest a reason why the Cascade Arc volcanoes are surrounded by volcanic rocks in northern California, Oregon and southern Washington, but are not farther to the north. (HINT: Pay attention to the direction the crustal blocks are moving.)

Hazards:

13. How do the hazards represented in this crustal block model **differ** from those associated with the Cascadia subduction zone? (See your answer to question 4 in Part A)

14. How are they similar and related to those of the Cascadia Subduction Zone?

Pacific Northwest Tectonic Block Model

Instructions:

Using this handout and the map provided, use the Pacific Northwest Tectonic Block Model to gain a better understanding of how plate tectonics influences Pacific Northwest geology.

Part A: The Plates

Place a mark in the box after you have completed each step:

Circle the names of the three major tectonic plates labeled on the map.

1. Which two plates are interacting at the Cascadia Subduction zone?

The Juan de Fuca and the North American plates

2. Which plate is being subducted? How do you know?

Answers will vary (using the key in the upper right hand corner of the diagram). Could include the presence of the Cascades Volcanic Arc as an indication of the subduction.

3. How does this subduction lead to the formation of the Cascades Volcanic Arc?

The water being released from the subducting plate (JDF) causes melting in the upper mantle. This magma rises toward the surface to eventually produce volcanoes.

4. What types of earthquakes does the Cascadia subduction zone produce?

Large to very large magnitude earthquakes.

a. Are they typically large earthquakes?

Yes.

b. When was the most recent large earthquake on the Cascadia subduction zone?

1700 A.D. (Approx. 300 years ago.) More specifically 26 January 1700

c. What other geologic event can occur with large subduction zone earthquakes?

Tsunami can occur with large subduction zone earthquakes

Part B: The Crustal Blocks

Using the model, locate the three major tectonic blocks on the western edge of the North American Plate.

Identify the **Sierra-Nevada** block on your map. Lightly shade it in **purple**.

Color in the arrows on the Sierra-Nevada block in **yellow**.

In which compass direction does it move with respect to interior North America? (Circle your choice)

North South Northeast **Northwest**

What is the approximate rate of movement of this block relative to the North American Plate?

11 (mm/yr)

Identify the **Coast Range block of Oregon** on your map. Lightly shade it pink.

Color in the arrows in yellow.

In which compass direction does it move with respect to interior North America? (Circle your choice)

North South Northeast **Northwest**

ANSWER KEY page 2/3

- What is the approximate rate of movement of this block relative to the North American Plate?
_____ 12 _____ (mm/yr)
- Identify the **Western Washington** block on your map. Lightly shade it in green.
- Color in the arrows in yellow.
- In which compass direction does it move with respect to interior North America? (Circle your choice)
North South Northeast Northwest
- What is the approximate rate of movement of this block relative to the North American Plate?
_____ 6 _____ (mm/yr)

To answer the following questions, it will be helpful to use the model to move the crustal blocks. You'll want to pay particular attention to HOW the plates interact with each other when moved.

1. Which crustal block is moving the most to the west?
The Coast Ranges of Oregon
2. Which crustal block is moving the most to the north?
The Sierra Nevada block Notice that the Sierra Nevada Block is moving more than the Western Washington Block is moving. (You can tell this by the length of the arrows that you colored yellow).
3. What geologic feature prevents the Western Washington block from moving any farther to the north?
The Canadian Coast Mountains Buttress
4. What is pushing the Western Washington block to the north?
The Coast Ranges of Oregon
5. If the Western Washington block cannot go any farther to the north but is still being pushed from the south, how is the crust in Western Washington going to respond?
It is going to fold and fault to accommodate the compressional stresses.
6. How is the crustal block in Oregon going to respond to being pushed from the south, but stopped by the Western Washington block?
It is going to fold and fault to accommodate the compressional stresses.
7. What types of features (**mountains, folds, faults**) are going to be formed as a result of these movements? Where are these features going to be located? Are they already present? **Color these features red on the map. (Hint: Look at the key in the upper right hand corner!)**
There are many faults on the map. And the Yakima fold and thrust belt.
8. You just colored in the major faults in the Seattle and Portland areas. What types of faults are they?
Many strike-slip faults and thrust faults.
9. Describe the types of earthquakes they are likely to produce. (Deep and/or shallow, large and/or small, frequent and/or rare, etc.)
Mostly shallow, small to medium in size, frequent earthquakes.

ANSWER KEY page 3/3

Identify the **Cascades Volcanic Arc** on your map using the larger model. Color in the volcanoes in **red** and the surrounding volcanic rocks in **orange**. *IMPORTANT: Notice that the Cascade Volcanoes in northern Washington and southern Canada are not surrounded by orange volcanic rocks.*

10. The Cascades Volcanic Arc lies to which side of the three crustal blocks you have already identified:
(Circle your choice)

North South East West

11. Where does the lava that forms these volcanoes come from?
From melted upper mantle which mixes with the overlying North American Plate.

Notice that the volcanoes start in northern California and extend north to central Washington.

12. Suggest a reason why the Cascade Arc volcanoes are surrounded by volcanic rocks in northern California, Oregon and southern Washington, but are not farther to the north. (HINT: Pay attention to the direction the crustal blocks are moving.)
Answers will vary. Extension (caused by westward movement of the Sierra Nevada and Coast Range blocks) in the southern part of the range has allowed magma to reach the surface in greater volume.

Hazards:

13. How do the hazards represented in this crustal block model **differ** from those associated with the Cascadia subduction zone? (See your answer to question 4 in Part A)
The earthquakes will be different. The movement of the crustal blocks causes smaller, more frequent local earthquakes whereas the subduction zone will produce large, infrequent earthquakes and likely associated tsunamis.
14. How are they similar and related to those of the Cascadia Subduction Zone?
Both produce earthquakes that can cause damage to structures and potential loss of life. The hazards associated the crustal block movement (small, more frequent earthquakes) are a result of the larger tectonic setting that includes the Cascadia Subduction Zone.

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