APPENDIX I: Instructor Answer Keys for 20-Min Activity Summary Handout and 45-min Learner Outline

20-Minute Summary Handout: GPS Station Movement and Land Deformation – ANSWER KEY

Name		Period/Class		Date	

Use this handout to summarize the kinesthetic activity using current GPS data to show how the land beneath our feet is moving, crumpling, sliding, and stretching.

Procedure and Questions

1. In the space to the right, sketch a vector. Label the head, tail, and where a GPS station would be located.



Complete the following sentence about vector length:
The longer the vector, the ***faster*** *the GPS station is moving.*

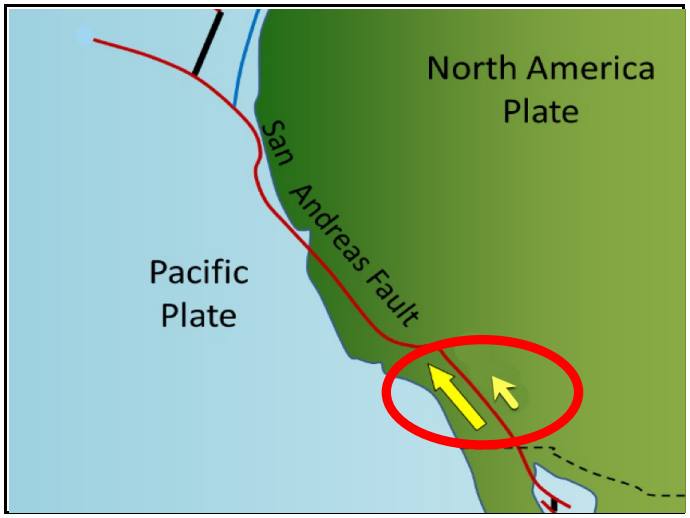
2. The map to the right shows the motions of the major tectonic plates on the west coast.

   a. Locate the vectors on either side of the San Andreas Fault.

   b. In your own words, explain what the vectors indicate.

   The vectors indicate that the Pacific Plate is moving faster than the North American plate because the vector on the Pacific Plate is longer.

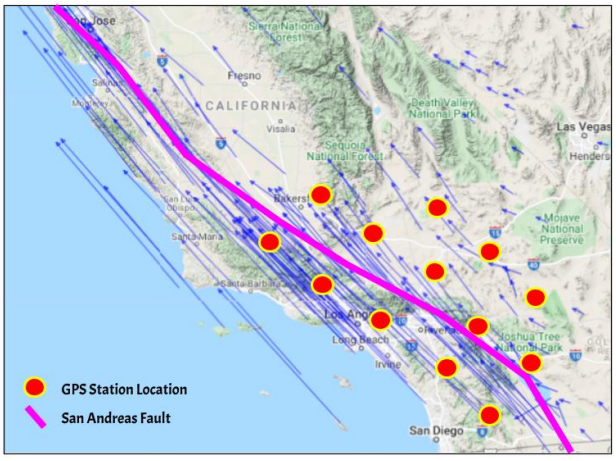
Where two tectonic plates slide past one another is known as a **transform boundary**. The San Andreas Fault is the best-known transform boundary in the United States.

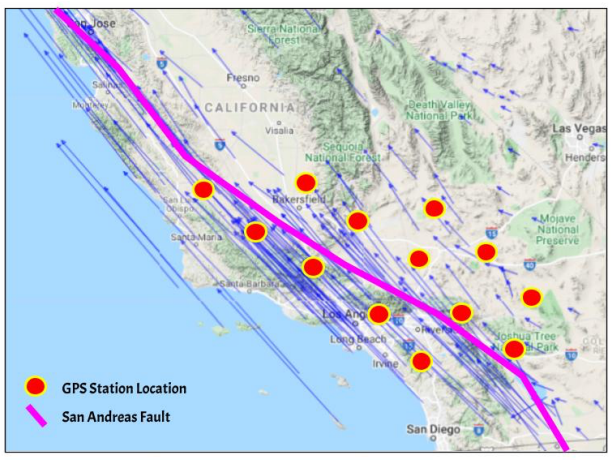


3. In the activity, elastic bands were used to connect different people standing on different GPS station locations. What does the elastic material represent?

The elastic material represents the land connecting all the GPS stations. As the material stretches, it simulates the land being deformed.

4. On the diagrams below, each dot represents one of the GPS stations that you just modeled. The image on the left is 'before' the movement, and the image on the right is where the GPS stations have moved over a period of time.





5. In your own words, explain what is happening to the land along the San Andreas Fault. Feel free to draw on the image to help explain your thinking.

Doing the activity shows the land along the San Andreas Fault is getting deformed, buckled, and stretched as the west side of the fault is moving faster than the east side of the fault. The farther the Pacific Plate moves, the more the deformation. Eventually, this could lead to the land breaking in an earthquake.

45-Minute Learner Outline: Exploring GPS Vectors and Crustal Motion – ANSWER KEY

Name		Period/Class		Date	

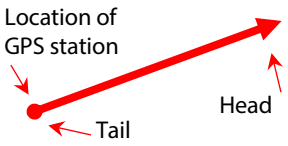
Are tectonic plates still moving? How do we know? Let's explore evidence of tectonic plate motion using current GPS data to see how the land beneath our feet is moving, crumpling, sliding, and stretching.

In this activity, you will either study posters or use vector map handouts (either the Tectonics Motions of Southern California or Tectonics Motions of Oregon and Washington) to do the following things:

1. Measure the amount of ground motion in multiple areas indicated by GPS data.
2. Analyze evidence of different types of crustal motion based on GPS data, and act out motions.
3. Consider the hazards and societal impact that might result due to these motions.

SECTION A: Measuring Ground Motion with GPS Vectors

Procedure and Questions

1. In the space to the right, sketch a vector. Label the head, tail, and where a GPS station would be located.		Complete the following sentence about vector length: *The longer the vector, the* ***faster*** *the GPS station is moving.*
2. On your map, circle the vector scale bar. The scale bar on this map is a 1:1 scale. This means that the length of the vectors on the map show the actual average distance the GPS station moves in a year.		
a. What is the length of the scale bar arrow? b. Therefore, how many millimeters of GPS station movement does the arrow represent?	A. ___10___ millimeters B. ___10___ millimeters	
3. Indicate which map you are working with by circling the name.	**Southern Calif. (in blue)** or **Ore/Wash (in green)**	
4. Using the North arrow, what direction do most of the vectors point?	**SoCal = northwest** **OR/WA = east, northeast**	
5. Measure the longest vector. How long, in millimeters, is the vector?	**About 45 mm** or **about 18 mm**	
6. While the amount the ground moved in one year may not seem like much, multiply it by 100 to show how far it would move in 100 years.	**45 mm/year x 100 years = 4500 mm** **18 mm/year x 100 years = 1800 mm**	
7. Divide the total number of millimeters moved by 1000. This will convert millimeters to meters moved in 100 years. Think of how far it will move in 1 million years!	**4500 mm/100 years ÷ 1000 = 4.5 meters** **1800 mm/100 years ÷ 1000 = 1.8 meters** **(450, 000 meters** **180,000 meters)**	

SECTION B: Understanding Crustal Motion using GPS Data

8. Pick a vector in the coastal area. Using one of the colored pencils, circle it and measure it. This is the annual movement of that coastal GPS station.
9. Pick a vector in an inland area that is clearly a different size than the coastal one. In a different color, circle it and measure it to find the annual distance moved.

10. In the space to the right, complete the statement using the data you measured.

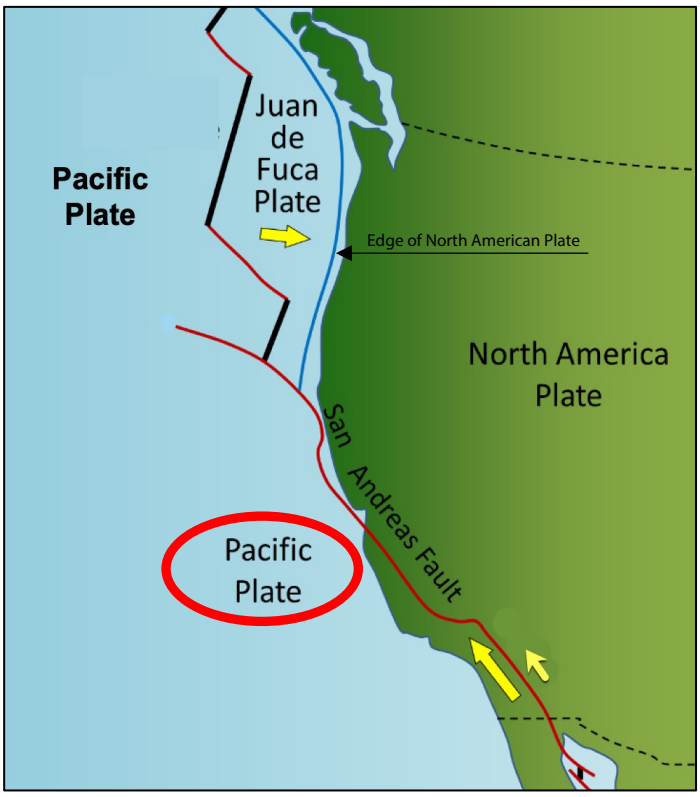
The coastal GPS station moved _____ mm in one year compared to the inland GPS station that moved _____ mm in one year.

(Answers here will vary anywhere between 1 mm/yr to 45 mm/year depending on the vectors chosen)

11. Draw a circle around the entire area along the coast that shows a higher amount of movement. Use the same color as you did when circling the vector from the coastal area.

12. Do the same for the area east of the coastal areas that shows motion in the same direction, but in general has less motion. Use the same color as you did when circling the vector from the inland area.

13. Use the image to the right to circle the name of the tectonic plate that appears to be moving the quickest.



14. Which of the following choices best describes the motion that the tectonic plates are showing? Circle the choice.

    A. *Tectonic plates are moving in opposite directions and are getting farther away from each other.*

    B. One tectonic plate is moving towards another one and running into it.

    C. One tectonic plate is sliding past another one that's moving in the same direction, but slower.

15. Where two or more tectonic plates interact, it is called a **plate boundary**. Based on the information provided by your instructor, what is the type of plate boundary that exists on your map . . .

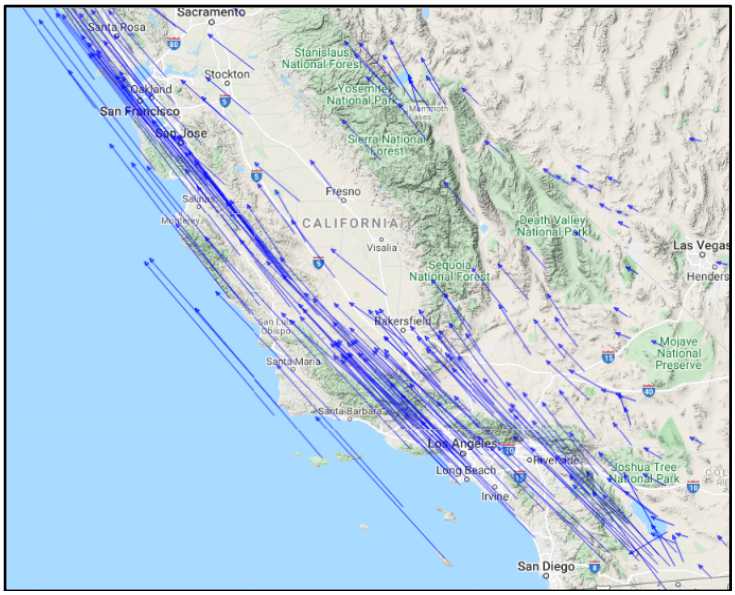
    a. Between the Pacific Plate and North American Plate:
    ___ ***Transform Boundary*** _____

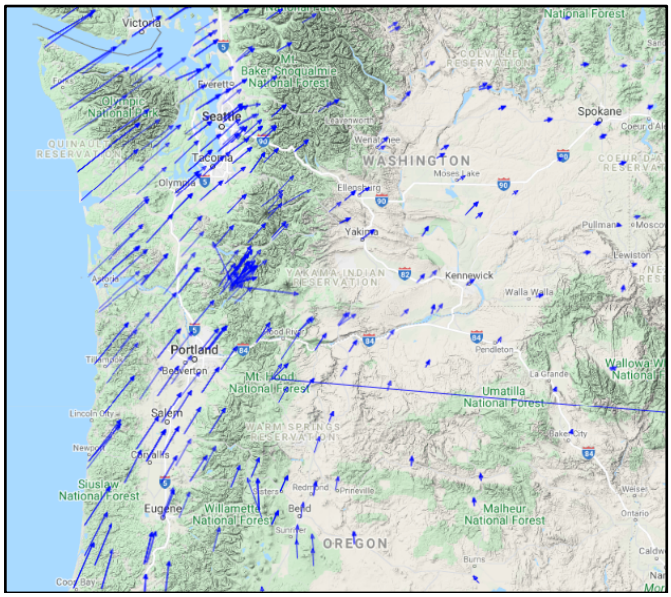
    b. Between the Juan de Fuca Plate and the North American Plate:
    ___ ***Convergent Boundary*** _____

SECTION C: USING GPS DATA TO DETERMINE POTENTIAL HAZARDS

GPS data show that some regions of the Earth's surface are moving faster than others. This causes deformation of the ground surface in those areas, and it leads to earthquakes when the ground finally breaks. Knowing where the ground motions are unequal can indicate areas of greater danger.

Below are GPS vector maps for the same areas you have been studying in Section A. The difference is simply in the number of GPS data vectors that are shown. The maps used in Section A limited the number of vectors shown to make it easier to find and measure individual vectors. Here are nearly all (CA) and all (OR/WA) the GPS data. It paints a slightly different picture.





16. Make observations on the two maps. Besides having more vectors, what else do you notice? What stands out?

Observations will vary and should include: - ***Lots of vectors clumped together (extra monitoring around Mt. St. Helens)*** - ***Super long vectors mostly along the coast.*** - ***Shorter vectors further inland.*** - ***Tiny vectors far inland.*** - ***A couple of vectors seem to not be pointing the same direction as most of the others.***	***Observations will vary and should include:*** - **Shorter vectors overall compared to CA.** - **Longer vectors along the coast the farther north you go.** - **Large clump of vectors in west central WA** - **Twisted appearance of overall vectors**

17. Using the same colored pencils as you used before when circling areas of different vector length in questions 11 and 12 above, lightly shade the maps for the areas you circled. Try to accurately pinpoint the transition from faster moving areas to slower moving areas.

18. Using a third color, shade in the areas much further inland that have very little motion as indicated by GPS data.

Now, compare your circled areas above on your maps to the Earthquake Shaking Potential Maps of California, Oregon, and Washington that your instructor will show you.

19. What is the correlation between your colored areas on the GPS Vector maps and the Earthquake Shaking Potential maps? What did you observe when you compared your colored maps to the official shaking potential maps?	***Learners should see a direct correlation between their coloring and the EQ Shaking Potential maps. They will see the areas of largest vectors will be the most hazardous and the smaller the vectors, the smaller the shaking potential.*** ***An exception is the very obvious high-hazard region right along the San Andreas fault. Learners should recognize that is the area of highest difference between vector lengths in a smaller area.***

A common misconception about GPS data is that the density of GPS stations indicates the areas that have the highest risk. While they may be related, this isn't necessarily true in every case.

20. Circle the statement, or statements, to the right that you believe to be true. 21. After discussion, cross out the statements that are false.	~~*A. The number of GPS stations in an area automatically means there is more danger there.*~~ ***B. The density of GPS stations is just that - there are more GPS stations in a given area.*** ~~*C. A GPS station with the longest vector will be the place with the largest earthquake potential.*~~ ***D. Areas with a big difference between the lengths of GPS vectors are the areas of higher risk of earthquake shaking.***

Connect back to the scenario of the GPS data in California using the elastic material.

22. What did the elastic material represent? What was modeled in the activity with the elastic material, and why is that important?	*The elastic material represents the land connecting all the GPS stations. As the material stretches, it models the land being stretched and deformed and increases the risk of it breaking. This is important because it simulates the potential breaking of the land, which is an earthquake.*
23. Brainstorm: What object(s) or material(s) might be used to model the converging tectonic motions of the Pacific Northwest?	*Answers will vary but might include springs, wood, plastic, spongy material - anything that deforms when stretched but wants to spring back to its original shape.*
24. Whether you have a transform boundary or a convergent one, why might it be beneficial to know what type of boundary it is. How do GPS data play a role?	*Knowing what type of boundary exists would allow scientists to predict what type of motion to expect, and direction of movement. Knowing GPS also allows scientists to have an idea of rate of movement, therefore how much potential energy is building up.*
25. What might be the impact on your life? School? Society?	*Responses here will vary and will incorporate multiple perspectives on how far reaching earthquake safety needs to be. The key is awareness and preparation. If we use the scientific information we learn from GPS, we can turn it into situational awareness and save myriad lives and infrastructure, and can build a more resilient society.*

The ShakeAlert ® Early Earthquake Warning System incorporates high-precision GPS data. Being aware of higher risk areas allows scientists and public health officials to mitigate the risk and produce far more favorable outcomes in the case of a major earthquake. For more information refer to the USGS ShakeAlert website.