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Started on	Tuesday, August 2, 2022, 3:27 PM
State	Finished
Completed on	Saturday, August 6, 2022, 6:35 AM
Time taken	3 days 15 hours
Marks	32.55/39.00
Grade	**83.46** out of 100.00

Question 1

Correct

1.00 points out of 1.00

Flag question

Tutorial I: Locating Seismic Events Using a Process of Elimination - The Bisector Method

The point on Earth's surface directly above where the earthquake rupture starts is called the epicenter. By comparing the arrival times of P-waves at different pairs of seismic stations, it is possible to identify geographic regions of Earth where an earthquake's epicenter cannot be located. This approach is called the Bisector Method. As you have learned previously, P waves radiate outward from the earthquake source in all directions. If we assume that the P waves travel with a constant velocity in all directions, then between any two stations, we can determine which station was closer to the event by examining their seismograms; the closer station will always record the P wave first. If we think about the geometry of this on Earth's surface, this means that for each pair, we could eliminate an area of the map as a possible location for the epicenter (the area containing the farther station). By repeating this comparative process between many pairs of stations we can eventually eliminate enough of Earth's surface to be left with a relatively small region where the event most likely occurred.

Let's get started! - To access the event we want to locate, use this link: https://www.iris.edu/app/eq-locate/method/1/event/10400146/stations/

This should open a map centered on the Korean Peninsula. On the map you will see a number of triangles. Each triangle represents a seismic station. Here you are to select stations that we want to use in our earthquake analysis. At least 4 stations must be selected, but you will get a better result if you select a number closer to the maximum amount (12). It is important that the stations selected are distributed on all sides of the event. Otherwise, we could be left with a "blind spot" that prevents us from narrowing down the range to a reasonably sized area.

Thinking like a seismologist you will want to select the station that is closest to the region you suspect the source to be located in. The triangle for these stations can be found near the center of the map with a dot in the center of them.

If you hover your mouse over this station the station code will appear. In this case it is a three or four letter/number station code followed by a space and then a two letter network code. What is the four letter station code for the station closest to where the earthquake occurred?

Hint: There are 4 stations marked as the closest to the earthquake. You only need to enter one of those stations.

Answer: SEHB ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 2

Correct

0.67 points out of 1.00

Flag question

Now we need to identify a few more stations to pick. We should be mindful that as seismic waves radiate outward from their source they attenuate or decay. This occurs partly for geometric reasons because their energy is distributed on an expanding wave front. It also occurs because their energy is absorbed by the material they travel through. Therefore, which of the following rules of thumb might make sense to guide our selections. Select all that apply.

Select one or more:

- [x] a. If M<6, choose stations closer to the region we suspect the event to have occurred. ✓ 1 of 2 correct answers
- [ ] b. The magnitude of the event is irrelevant to the stations we should select.
- [ ] c. If M<6 the distance of the station to the suspected event is of less importance and we can choose any station.
- [x] d. If M>6, the distance from the station to the suspected event is of less importance and we can choose any station. ✓ 1 of 2 correct answers
- [ ] e. If M>6, choose stations closer to the region we suspect the event to have occurred.

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 3

Correct

1.00 points out of 1.00

Flag question

What is the magnitude of the event we are investigating as indicated in the upper left corner?

Answer: 6.3 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

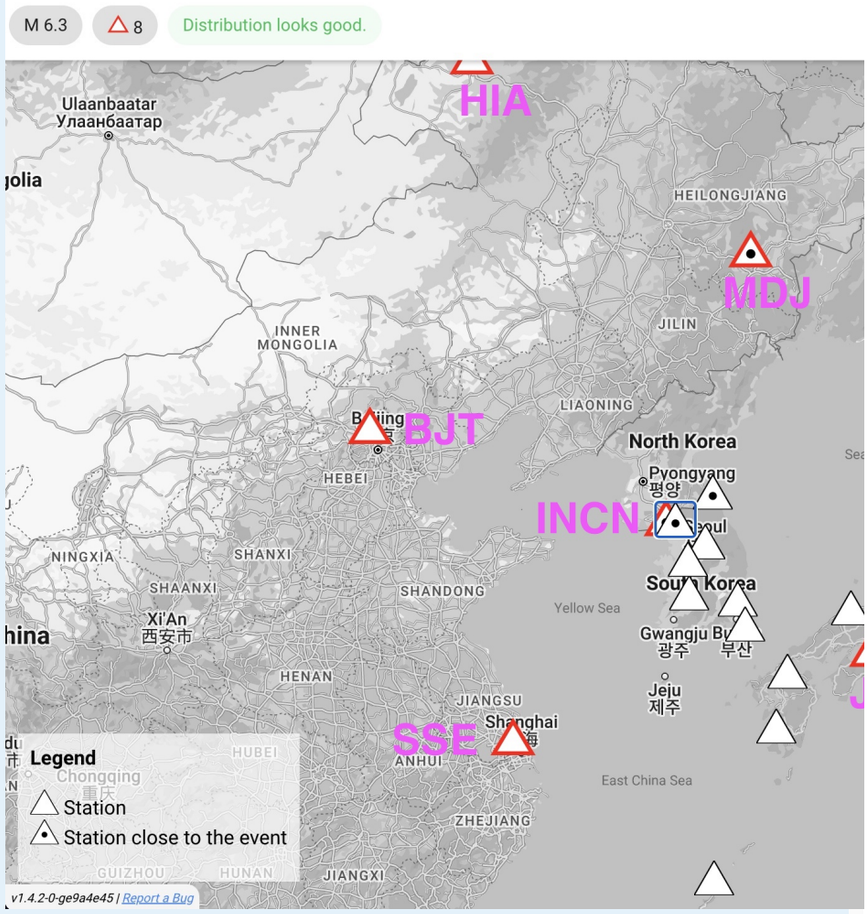
Question 4

Correct

1.00 points out of 1.00

Flag question

Since this event is right on the borderline of the rules of thumb above, let's choose both some that are close and some that are farther away. Select these stations that are shown on the map below: HIA, BJT, INCN, SSE, JMN, MDJ, JYT, YSS.



Using their general location can get you close but in some areas where there are lots of stations you will need to hover over and be sure you are selecting the correct stations.

Using the counter in the upper left corner how many stations did you select?

Answer: 8 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 5

Correct

1.00 points out of 1.00

Flag question

What does the tool say about the distribution of the stations you selected?

Select one:

- a. Distribution: Select more stations to the: South East
- b. Distribution: Select more stations to the: North West
- c. Distribution: Looks Good ✓
- d. Distribution: Select more stations to the: North East
- e. Distribution: Select more stations to the: South West

Check

Correct
Marks for this submission: 1.00/1.00.

Question 6

Correct

1.00 points out of 1.00

Flag question

Once you have selected stations, click “Next” in the upper right corner to inspect the seismograms from the stations you picked.

As you have learned in the previous module, simply because the station exists, it does not mean that data is necessarily available for the time you are interested in looking at. It also does not mean that the data you get will be usable for the analysis we would like to conduct. Thus, your next task is to complete a quality check or quickly inspect the seismograms from the stations you selected for usability and delete any that will not work.

Quickly scan the seismograms to see if any stations have no data (we will address poor data in the next question). Which of the following stations are not usable due to lack of data availability and should be deleted? Select all that apply.

Select one or more:

- a. SSE
- b. INCN
- c. HIA
- d. YSS
- e. JYT ✓ Correct. Go ahead and click to Delete this station.

Check

Correct
Marks for this submission: 1.00/1.00.

Question 7

Correct

0.00 points out of 1.00

Flag question

Now that we have deleted stations for availability issues, we need to find and delete any stations that we will be unable to convincingly pick a P wave on. You have already picked P waves but recall that you are looking for the first notable change from the background noise.

Now review the seismograms. Which of the following stations are not usable due to poor data and should be deleted? Select all that apply.

Select one or more:

- a. INCN
- b. JYT
- c. YSS
- d. SSE
- e. None of the above ✓ While some may have been easier to pick than others, the data was good enough to use for all of them.

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.00/1.00**.

Question 8

Correct

1.00 points out of 1.00

Flag question

After completing your quality check and deleting any stations that you are unable to pick the time of the P arrival for the time period requested, how many stations are you left with to complete the location?

Answer: 7 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 9

Correct

1.00 points out of 1.00

Flag question

Now that we are left with usable data, let's begin the analysis by picking the P arrival for each station. Lets begin with station ENH. Click and drag the red vertical line to the right. As you move the line, note how the red (P:Time) changes at the top of the seismogram panel in the HH:MM:SS format. Time on a seismogram increases as you slide the slider to the right.

Move the red vertical line on HIA to 3:32:29.0 as your initial pick. Now use the +/- symbols on the right of the seismogram to zoom in (+) around the pick. What should you do to ensure the pick is accurate?

***NOTE**: If your time scale does not show 3:32:29.0, you may be in a timezone where the timezones are 30 min off (India, Sri Lanka, Afghanistan, Iran, Myanmar, Newfoundland, Venezuela, Australia; in some places 45 min off: Nepal) instead of a full hour. We have found that if you open the link in the OSL, the issue should be resolved. Let us know in Slack if you are still having difficulties.*

Select one:

- a. Move the pick flag to the right to 3:32:29.7 ✓ Correct. Go ahead and move the pick to this time.
- b. Move the pick flag to the left to 3:32:27.1
- c. Move the pick flag to the right to 3:32:30.5
- d. Leave the pick flag at 3:32:29.0

Check

Correct
Marks for this submission: 1.00/1.00.

Question 10

Correct

1.00 points out of 1.00

Flag question

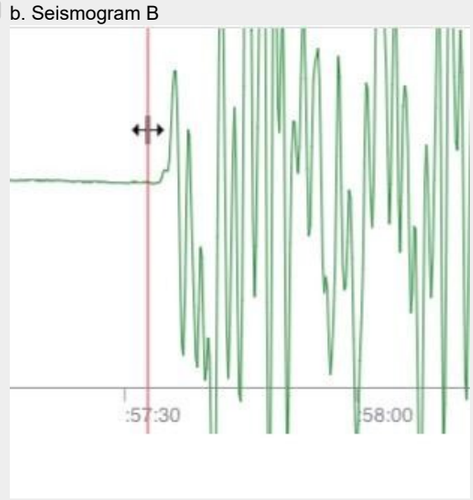
Which of the following images show accurately picked P arrivals? Select all that apply.

Select one or more:

a. Seismogram A

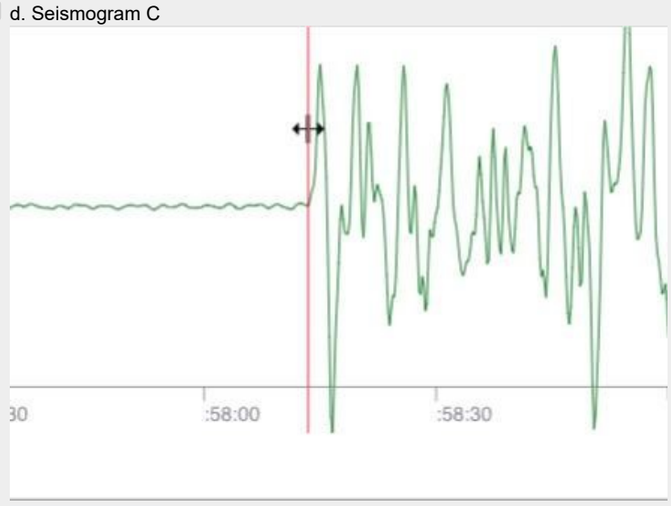
1 of 2 correct answers

b. Seismogram B



c. Seismogram D

d. Seismogram C



1 of 2 correct answers

Check

Correct
Marks for this submission: 1.00/1.00.

Question 11
Correct

Now make your initial and refined picks for each of the remaining stations by placing the red line for each of the seismograms and using the (+/-) zoom buttons to help.

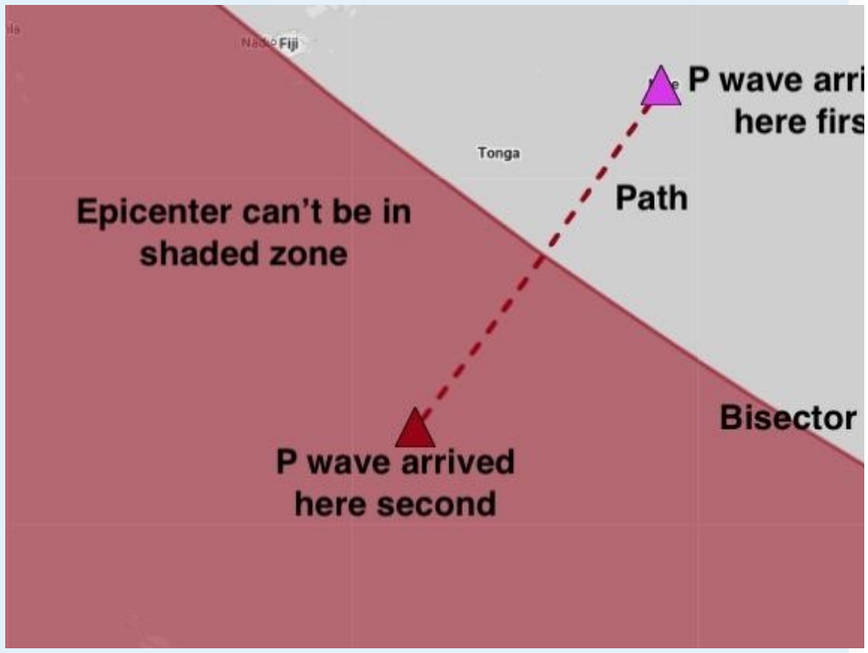
0.67 points out of 1.00

Flag question

When you complete this, click Next in the upper right so you can begin to use the picked arrival times to locate the earthquake. Remember, the bisector method of location we are using is an iterative comparative process of eliminating geographic regions where the epicenter could not be located based on which station had the first arrival.

The process begins by selecting 2 stations from the map. Let's choose two of the farthest stations so we can essentially eliminate half of the map area; station YSS (NE corner) and station SSE (SW corner). These stations will be connected with a dashed line called the “path”, and a small pop-up window will display the seismogram for each station along with your P picks. Your job is to compare the two seismograms and determine which of the pair the P wave arrived at first. Note that you may need to use the (+/-) buttons to zoom in/out, or pan the seismograms by clicking and dragging right or left to go forward or backwards in time. Once you have determined which station recorded the P wave first, use the radio buttons to select that station.

Based on your selection, the application will draw a bisector: a straight line that passes through the midpoint of path and is perpendicular (90 degrees) to the path. All points on the bisector are equidistant from the two stations connected by the path. The side of the bisector where the seismogram arrived second will be shaded, as we can eliminate that region as a possible location for the epicenter.



Which of the following best describes why the half of the map containing the station you selected above was shaded? Select all that apply.

Select one or more:

- [x] a. Since the P wave arrived later at SSE, it must be farther away from the epicenter than station YSS. Therefore, the side of the bisector containing SSE cannot contain the epicenter and is therefore shaded out or eliminated as a possible solution. ✓ 1 of 2 correct answers
- [x] b. Since the P wave arrived at YSS first, the side of the bisector containing YSS must be closest to the epicenter and the side containing SSE can't contain the epicenter and is therefore shaded out or eliminated as a possible solution. ✓ 1 of 2 correct answers
- [ ] c. Since the P wave arrived later at SSE, it must be farther away from the epicenter than station YSS. Therefore, the side of the bisector containing SSE must be shaded as that side must contain the epicenter.
- [ ] d. Since the P wave arrived at SSE first, it must be closest to the epicenter. Therefore the side of the bisector containing YSS can't contain the epicenter.

Check

Correct

Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 12

Partially correct

0.75 points out of 1.00

Flag question

Continue to select more station pairs and compare their seismograms to further narrow down and define the space where the epicenter can not be located. It is not uncommon to have more than 20 station pairs in trying to narrow down the space where the epicenter could be located.

Once you are satisfied that you can't create any more station pairs to compare, toggle the “Select Solution” button in the upper right corner. This will switch the tool into a mode that allows you to define the boundary of your solution area (the unshaded region you couldn't rule out based on the stations you selected). Do this by selecting the orange circle markers at the intersection points of the shaded/unshaded areas. As you touch each intersection point, your solution area will fill in with red. Make sure you select the intersect point in consecutive order around the perimeter of your region. Congratulations you have just located the region where this event likely occurred!

Now, to compare your solution region to the accepted USGS location for the event click “Finish”. How large of a region was your solution (listed towards the top of the results page)? You can just answer a number and I will assume your answer is in square miles.

Answer: 6088.6

Check

Good job. Try adding more stations or refining which station had the first arrival picks.

Partially correct

Marks for this submission: 0.75/1.00.

Question 13

Correct

1.00 points out of 1.00

Flag question

How did your solution compare to the USGS solution? If your solution did not contain the official USGS location, you should check the station pairs list at the bottom of the page. For each pair you used, it will display whether you correctly picked the arrivals or not. It will also show you pairs you could have picked but did not select. If you would like you can toggle these extra pairs on and see if any of them could have helped to further refine your solution. For our records, choose which of the following describes your solution and how many picks you got correct and incorrect. You will receive full credit for this question as long as you report all 3.

Select one or more:

- [x] a. The USGS solution was contained inside my solution area. ✓
- [x] b. I had between 5 and 9 incorrect picks. ✓
- [x] c. I had between 0 and 4 correct picks. ✓
- [x] d. I had between 15 and 20 incorrect picks. ✓
- [x] e. I had between 10 and 14 correct picks. ✓
- [x] f. I had between 0 and 4 incorrect picks. ✓
- [x] g. The USGS solution was not contained inside my solution area. ✓
- [x] h. I had between 5 and 9 correct picks. ✓
- [x] i. I had between 10 and 14 incorrect picks. ✓
- [x] j. I had between 15 and 20 correct picks. ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 14

Correct

0.33 points out of 1.00

Flag question

Accuracy refers to the closeness of a measured value to a standard or known value. Precision refers to the closeness of two or more measurements to each other. If the USGS solution represents a high degree of accuracy and precision, which of the following best describes the accuracy and precision of your solution.

Select one:

- a. High degree of accuracy and low degree of precision
- b. Low degree of accuracy and precision ✓
- c. High degree of accuracy and precision
- d. Low degree of accuracy and high degree of precision

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.33/1.00**.

Question 15

Correct

0.67 points out of 1.00

Flag question

Which of the following assumptions did we need to make for this location technique to work? Select all that apply.

Select one or more:

- [x] a. That P wave velocities are consistent in all directions horizontally. ✓ 1 of 2 correct answers
- [ ] b. That the earthquake occurred at a shallow depth.
- [x] c. That all P wave picks were made by applying a consistent procedure to decide where to pick. ✓ 1 of 2 correct answers
- [ ] d. That P wave velocities vary in all directions horizontally.
- [ ] e. That all stations have excellent data quality.

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 16

Correct

1.00 points out of 1.00

Flag question

Think for a moment about the comparative process you used to locate the region this event occurred in and where you eventually found the location to be relative to the stations you used. Could you have gotten a similar solution location simply by assuming the event was near (within 100 km square) the station with the earliest P wave arrival (MDJ)?

Select one:

- a. Yes ✓ Correct. Because the world is pretty well instrumented, assuming the location of the event is at the closest station frequently gets you close to the event's actual location. In this way it can be a good starting point for more iterative location approaches.
- b. No

Check

Correct
Marks for this submission: 1.00/1.00.

Question 17

Correct

1.00 points out of 1.00

Part II: The Modern Approach to Earthquake Location: Residual Minimization Method

Flag question

In Part I of this Tutorial, you used a simple geometric approach to locate the region where an earthquake occurred. However, as you saw at the end when you compared your solution space to the accepted location for the event, you found that seismologists are able to be much more precise and often a higher level of accuracy. They are able to identify the point inside the Earth where an earthquake rupture starts (hypocenter) and when the event occurred (origin time). Seismologists can calculate, within some level of error, this location and the event time by using the observations of the seismic waves it produces. This process of calculating the solution from observations that were produced by the causal factors is called an inverse problem. The introduction below provides a simplified introduction to the modern approach to locating earthquakes with the goal of enabling you to understand what is happening while you use the location tool. If you are interested in learning more about this approach or the math behind it, we encourage you to check out a few of the optional resources for this module.

Determining the location of the hypocenter as an inverse problem begins by carefully examining seismograms from the event and identifying when, in clock time, the P wave arrived at each station. This observed pick time is a clock time (HH:MM:SS) usually reported in Coordinated Universal Time (UTC). These observed pick times are then compared to a predicted pick time for each station. The predicted pick time is derived from a model constructed from the observations of many, many past earthquakes. This velocity model is used to calculate a predicted travel time or the amount of time it should take a P wave to travel to any given location (e.g. where a station might be located), assuming that the source is in a particular location (earthquake's hypocenter). For this activity, we will first assume that the initial source location is at the station where the seismic waves arrive first (e.g. closest to the epicenter). Once we have a predicted travel time for each station we need to convert those into a clock time so we can compare them to the P wave pick time (which is a clock time). What do we need to accomplish this conversion?

Select one:

- a. the time when the earthquake occurred ✓
- b. the distance from the earthquake to the station
- c. the time zone where the station is located
- d. the time zone where the event is located

Check

Correct
Marks for this submission: 1.00/1.00.

Question 18

Correct

1.00 points out of 1.00

Flag question

A trial origin time is generated by taking the predicted travel time for each station and then subtracting that from the observed pick time at that station. This gives us a model origin time for each station. All the event origin times for the stations are then combined and averaged to give us an estimated model origin time. Predicted pick times are then calculated for each station by adding the predicted travel time to each station to the estimated model origin time.

Then the observed pick time for each station is compared to the predicted pick time for each station. While not the actual equation used, you might think of the comparison process for each station as shown below.

Pick Time $_{observed}$ - Pick Time $_{predicted}$ = residual

The smaller the residual, the more closely the predicted picks match with the observed picks. In turn, this means that the source location used for the calculations is closer to where the actual hypocenter is located. The larger the sum of the residuals of all the stations, the farther away the estimated location used for the calculations is from the actual hypocenter.

The residuals are reduced in an iterative fashion by adjusting the location of the source used for the calculations in a direction that is likely to reduce the residuals. Then the calculations are repeated, resulting in new predicted arrivals which are then compared to the observed arrivals. Ideally, what should happen during each iteration?

Select one:

- a. Each iteration should result in a smaller sum of residuals until some threshold is reached. ✓
- b. Each iteration should result in a larger sum of residuals until it plateaus.
- c. Each iteration should result in a smaller sum of residuals until it reaches zero.
- d. Each iteration should result in a larger sum of residuals until some threshold is reached.

Check

Correct
Marks for this submission: 1.00/1.00.

Question 19

Correct

1.00 points out of 1.00

Flag question

Today's computers assist seismologists in this process of identifying trial locations that help reduce the residual for each station. Working in this fashion iteratively, a computer can quickly calculate residuals for many potential locations until it finds an optimal location based on a set threshold for the sum of residuals. This is referred to as the best-fitting hypocenter. Rather than having the computer do all of this, we have developed a location tool that allows you to manually perform the steps of selecting the stations, picking the P wave arrivals, and adjusting the source location used for the calculations until you reach the smallest sum of residuals you can. Then you can compare the “solution” you came up with to the accepted solution for the event. It is important to note that the P wave velocity model used in this tool is highly simplified and not a perfect match to the real Earth. As a result, the residuals will never be zero and your location will never perfectly match that reported location, which was calculated using a more sophisticated model and more data.

Let's get started! - To access the event we want to locate, use this link: https://www.iris.edu/app/eq-locate/method/2/event/11176800/stations/

This should open a map centered on Cuba. On the map you will see a number of triangles representing seismic stations. What is the three or four letter station code for one of the stations that are closest to the event?

Answer: SJG ✓

Check

Correct
Marks for this submission: 1.00/1.00.

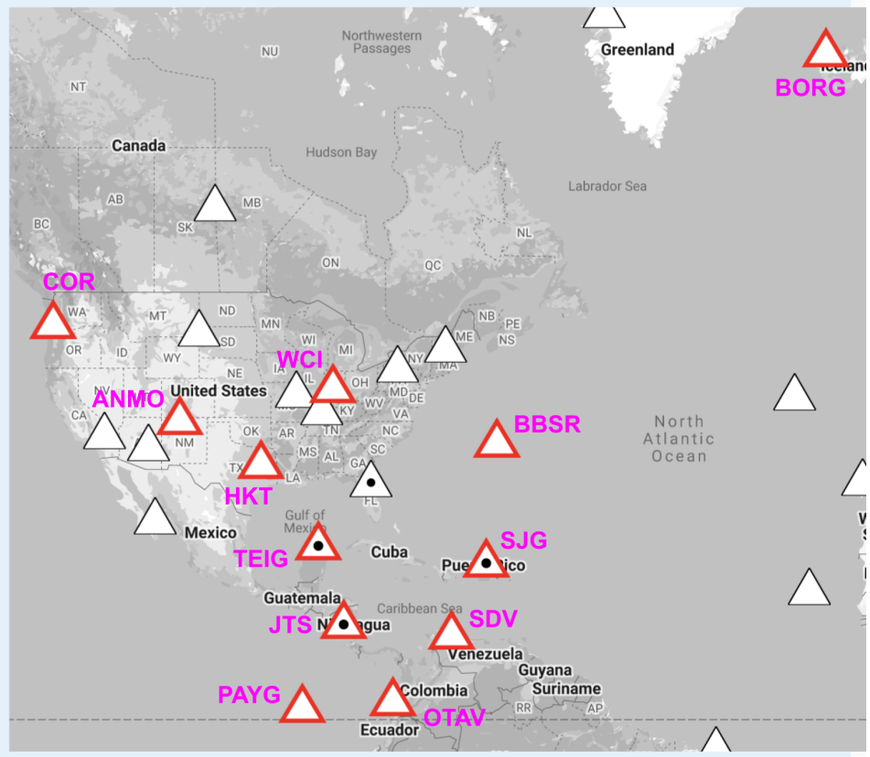
Question 20

Correct

1.00 points out of 1.00

Flag question

Now you need to select stations to locate the earthquake. At least 4 stations must be selected, but you will get a better result if you select the maximum amount (12). It is important that the stations selected are distributed on all sides of the event. Otherwise, we could be left with a "blind spot" that prevents us from narrowing down the range to a reasonably sized area. Applying the rule of thumb for M>6.0 earthquake, go ahead and select the following additional 12 stations that are evenly distributed around the suspected event location: BORG, TEIG, HKT, COR, SDV, SJG, BBSR, OTAV, PAYG, ANMO, JTS, WCI



Once the 12 stations are selected, click Next. As you learned in the previous tutorial, it is important to inspect the seismograms from the stations you selected and conduct a quality check for usability. Which of the following stations are not usable due to poor data OR the P-wave is not easily visible? Select all that apply.

Select one or more:

- [ ] a. TEIG
- [ ] b. WCI
- [ ] c. JTS
- [ ] d. ANMO
- [x] e. COR ✓ 1 of 3 correct. This station had bad data quality. Go ahead and delete this station.
- [x] f. SDV ✓ 1 of 3 correct. This station had bad data quality. Go ahead and delete this station.
- [ ] g. OTAV
- [x] h. BORG ✓ 1 of 3 correct. The P arrival is hard to pick confidently for this station. Go ahead and delete this station.

Check

Your answer is correct.

Correct
Marks for this submission: 1.00/1.00.

Question 21

Correct

1.00 points out of 1.00

Flag question

Once you deleted the unusable stations from Q20, how many stations do you have left to use?

Answer: 9 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 22

Correct

0.50 points out of 1.00

Flag question

The first step in our location routine is to pick the P arrivals for each station. Remember, we will be comparing observed arrival times to the predicted arrival times generated from the model. When you pick the P arrival you are setting the observed arrivals. Thus, this is a very important step! If you make careless picks, your comparison will be built on bad information. Garbage in… Garbage out!

Pick the first arrival for station SJG. Go ahead and zoom into the seismogram if necessary. Using the following format HH:MM:SS, enter the pick time the P wave arrived at station SJG.

Note that this is a time on the clock or a clock time.

Answer: 19:13:14 ✓

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.50/1.00**.

Question 23

Correct

1.00 points out of 1.00

Flag question

Go ahead and make your picks for all the remaining stations.

However, we will do a little something different for station BBSR. Pick the arrival at 19:12:08. Which of the following best describes the small wiggles (zoom may be required to see) on station BBSR at this time?

Select one:

- a. S wave
- b. Surface waves
- c. P wave
- d. Background noise ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 24

Correct

1.00 points out of 1.00

Flag question

Time on these seismograms runs from left to right. Thus, our pick at 19:12:08 would be best described as which of the following compared to the P wave arrival time?

Select one:

- a. More than a minute too early ✓ Good! For the sake of showing something later we'll keep this arrival time even though it's too early. Do NOT change the pick for this station.
- b. A few seconds too late
- c. More than a minute too late
- d. A few seconds early
- e. Just on time

Check

Correct
Marks for this submission: 1.00/1.00.

Question 25

Correct

0.67 points out of 1.00

Flag question

Once you are satisfied with your P picks, including the bad pick for BBSR, click “Next” in the upper right hand corner. **IMPORTANT: DO NOT CLICK ON ANYTHING YET ON THE MAP THAT APPEARS!**

The map you are looking at uses many common symbols you are already familiar with. For example, stations are still triangles and the stations closest to the event are highlighted with a black dot in the center. If you look carefully you will notice that one of these stations is partially obscured by a red place-mark. The red place-mark indicates the position of an initial guess for the epicenter used to calculate the predicted travel time. The green circle represents the best solution (e.g. lowest sum of residuals) you have achieved so far. Since you have not done anything yet, the place-mark is located right at the closest station and the green dot is set on the equator.

To activate the location process click on the red place-mark and move it slightly, but still close to the station it was near. When you do, the server your computer is connected to does the following things.
1) It set the initial location of the event to be the location where you moved the place-mark.
2) It used a simple velocity model to calculate predicted P wave arrival times from that initial location to each of the 8 stations you selected.
3) It compared the predicted arrival time to the P picks you made and calculated the residual between the two.
4) It combined the residuals for each station and created a single error statistic called the Root Mean Squared (RMS) value and displayed that value in the upper left corner.

You will also notice that there are red lines and a green arrow extending from the red place-mark. Which of the following statements best describes the combination of lines and arrows that you see?

Select one:

- a. There are no arrows or lines shown
- b. Several red lines and one green arrow ✓
- c. Several of small green lines and one large red arrow
- d. No red lines and multiple green arrows

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 26

Correct

Each red line indicates the residual between your observed P arrival time and the predicted arrival time for each station. The length of the line extending from the place-mark corresponds to the degree of error. So, a longer line means a larger error. The green arrow is the sum of all the

1.00 points out of 1.00

Flag question

red lines (direction and length). Looking at the length of the red lines you see, which of the following best describes them?

Select one:

- a. The error is large across all stations.
- b. The error for one station is larger than the rest. ✓
- c. The error is small across all stations.
- d. The error for most stations is large but there is one station with a small error.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 27

Correct

0.67 points out of 1.00

Flag question

We can also see the overall error for the model run by looking at the root mean squared (RMS) value in the upper left corner of the screen. You might think of this as a combination of all the residuals for all the stations. What is your current RMS value?

Answer: 81.03 ✓

Check

Correct

Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 28

Correct

0.67 points out of 1.00

Flag question

Considering what the server did to produce these lines, there are a few sources of error we can identify so far. First the picks could be wrong. Second, the location used for calculating the predicted arrivals could be wrong. Which of the following combinations is mostly likely the source of the error you see?

Select one:

- a. The P picks for all the seismograms are correct and the event did occur at the closest station.
- b. The P picks for all the seismograms are incorrect and the event occurred at the closest station.
- c. The P picks for most of the seismograms are incorrect and the event occurred at the closest station.
- d. The P pick for one of the seismograms is incorrect and the event did not occur at the closest station. ✓

Check

Correct

Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 29

Correct

1.00 points out of 1.00

Flag question

The tool allows us to use the lines to review our picks for each station by clicking on either the station itself or the error line that corresponds to each station. Let's investigate the longest line shown on the page. Carefully mouse over the end of the line farthest from the place-mark. When your cursor changes to a pointing finger, "Click" the line.

A seismogram will popup across the bottom of the screen. In the space below enter the four letter station code for the station that appeared.

Answer: BBSR ✓

Check

Correct

Marks for this submission: 1.00/1.00.

Question 30

Correct

0.67 points out of 1.00

Flag question

It should be no surprise that this single long red arrow is the station that we intentionally picked too early! Now, improve the pick for this station by adjusting the red slider bar to the right. Which of the following describes what happened?

Select one:

- a. Only the line for BBSR got shorter and no other lines changed.
- b. The line for BBSR got longer and the other lines also changed.
- c. The line for BBSR got shorter and the other lines also changed. ✓
- d. Only the line for BBSR got longer and no other lines changed.

Check

Correct

Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 31

Correct

1.00 points out of 1.00

Flag question

What is the new RMS value shown?

Answer: 71.76 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 32

Correct

1.00 points out of 1.00

Flag question

The line for BBSR obviously changed because the new pick more closely matched the predicted arrivals. However, the other lines also changed in the degree of error (length) and the green vector sum arrow also changed in length and direction. Which of the following best describes why the other lines and the green arrows also changed when the pick for BBSR was changed? Tip: You might want to go back to the beginning of the tutorial and re-read the introduction.

Select one:

- a. The velocity model used to calculate the travel times for all the stations changed.
- b. The initial source location used in the calculations changed.
- c. The picks for the other stations were based on the pick at BBSR.
- d. The estimated model origin time is derived from a combination of the pick times from all stations. ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 33

Correct

0.67 points out of 1.00

Flag question

Now, all our picks should be accurate or close to accurate, and we can begin to manipulate the solution by trying other source locations (indicated by the place-mark). Changing the guessed location will, in turn, cause the computer to calculate new predicted travel times for each new position… generate a new estimated model origin time..., and finally a new predicted pick times for all stations. These new predicted pick times will be compared to the observed pick times, and the differences will be conveyed by new red lines, the RMS statistic and green RMS arrow. Every time you move the place mark this process occurs even though the process appears seamless in the tool.

Close the seismogram for BBSR and zoom in on the place mark so we can adjust it. The first question we need to ask ourselves is which direction seems like the best direction to move the place-mark? In this case, the green arrow gives us a clue in terms of both magnitude and error. Which of the following best describes the direction the green arrow is primarily pointing?

Select one:

- a. South and West
- b. South and East
- c. North and West ✓ North and west is to the top left of the screen. If your green arrow is pointing in this direction you need to re-check your picks.
- d. North and East

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.67/1.00**.

Question 34

Correct

0.33 points out of 1.00

Flag question

Click on the place-mark and slowly drag it in the direction of the arrow a short distance. (Note: Sometimes it can be difficult to grab the place-mark, so you may need to be persistent.) As you slowly drag the place-mark, the RMS value in the upper left corner should get smaller and the green dot, which indicates the position of the lowest RMS value achieved will follow along. Which of the following best describes what the smaller RMS value means?

Select one:

- a. The predicted pick times, based on the placemark position, don't change. Only the estimated model origin time changes.
- b. The predicted pick times, based on the placemark position, more closely match the observed pick times. ✓
- c. The predicted pick times, based on the placemark position, increasingly fail to match the observed pick times.

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.33/1.00**.

Question 35

Correct

1.00 points out of 1.00

Flag question

Continue to move the place-mark in the direction the green arrow is pointing until you reach a point when the red lines become shorter than the green arrowhead. At this point, zoom in about four clicks, or until you can see the red lines and a green arrow again. Then move the place-mark again until the red lines become smaller than the green arrow head again and the green dot had now moved to a new lowest RMS point. Once you feel you have achieved a position with the lowest RMS value possible (on the green dot), what is that lowest RMS value?

Answer: 1.67 ✓

Check

Correct
Marks for this submission: 1.00/1.00.

Question 36

We can make a final adjustment to the placemark location by changing the depth of the marker to some depth beneath the surface by using the depth slider at the top of the screen. Which of

Correct

1.00 points out of 1.00

Flag question

the following best describes why this might improve a location?

Select one:

- a. Any change to the position of the placemark, in any direction including depth, will affect the distance the waves would travel to reach the stations. ✓
- b. Deeper earthquakes are more difficult to record.
- c. All earthquakes occur deep in Earth so setting this makes it more realistic.
- d. The P waves on the seismograms were very impulsive which means the earthquake must have been deep.

Check

Correct

Marks for this submission: 1.00/1.00.

Question 37

Correct

1.00 points out of 1.00

Flag question

Go ahead and move the depth slider deeper and shallower until you reach the lowest RMS value you can. Once you are satisfied, click compare results. How does your location compare to the reported location for this event? You will receive full credit for this question if you accurately report your score.

Select one or more:

- a. 5 Stars - Ready for a job as a seismologist! ✓
- b. 1 Star - Help!
- c. 2 Stars - Something went wrong with my picks!
- d. 3 Stars - Maybe a bad pick or two!
- e. 4 Stars - So close!

Check

Correct

Marks for this submission: 1.00/1.00.

Question 38

Correct

0.50 points out of 1.00

Flag question

If your answer above was 3 stars or lower, use the back arrow in the upper left corner of the screen to return to the seismogram view page. From there, you will be able to carefully reexamine each of your picks and then relocate the event.

Which factors are important to achieving the highest quality location possible? Select all that apply.

Select one or more:

- a. Observed P wave picks ✓
- b. Quantity of stations recording the event ✓
- c. Tectonic environment
- d. High-quality velocity model ✓
- e. Uniform distribution of stations ✓

Check

Correct

Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.50/1.00**.

Question 39

Correct

0.80 points out of 1.00

Flag question

Let's review. Examine all the phrases below that summarize steps in the modern process of locating an earthquake. As you probably noticed these phrases are out of order. Think back to the process you just experienced (and review Questions 17 and 18 in particular) to sequence these phrases in the order they occur. We realize that getting everything in the right order can be a little difficult, but going through this will help you to consider each of the steps in the process more closely.

If you would like to learn more about how this process works, here is a link to a nice explanation of the earthquake location process and some caveats to consider when looking at your results: https://pnsn.org/outreach/about-earthquakes/locating-eqs

A residual is determined for each station by subtracting the predicted arrival time from the observed arrival time	8 ✓
A travel time is predicted for each station using the source location	5 ✓
An arrival time is predicted for each station using the source location and estimated origin time	7 ✓
Identify the stations in the area	1 ✓
The origin time is estimated from subtracting the predicted travel times from the picked arrival times	6 ✓
Assume the initial source location is at the station with the earliest arrival	4 ✓
A new source location is selected to try to reduce the residuals	9 ✓
Pick the P wave arrival times on the good data	3

Review the quality of the recorded data to determine which stations to use	2
Iterate by calculating new residuals for each new source location until the lowest residuals are found	10

Check

Correct
Marks for this submission: 1.00/1.00. Accounting for previous tries, this gives **0.80/1.00**.

Finish review