**Relocating Ocean Bottom Seismographs by Inversion of Water Wave Arrival Times**

Ocean Bottom Seismographs (OBSs) are relocated using the water wave picks identified and picked using the tlPicker. Before proceeding with the inversion results, it’s important to understand the station and shot bathymetry.

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Station lost

36

**35**

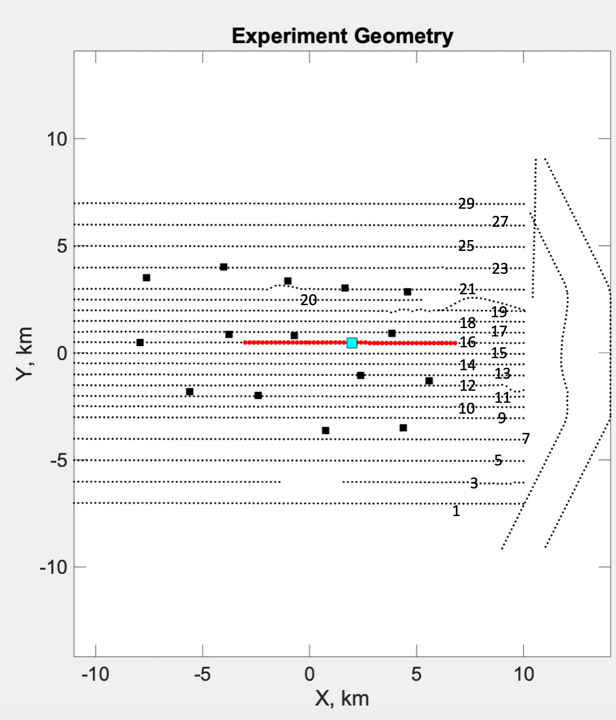
**34**

**33**

**32**

**31**

**30**

*Figure 1: Line Numbers and shot geometry Figure 2: Station numbers labeled along with the red shots*

*near the Orca Volcano red shots indicate denoting the shots selected within 5km of station 21 for*

*the extent of line 16 shots selected for station 21 water wave picking*

The figure 1 showcases the numbering of the Lines with respect to the station geometry. The red line on this figure is a potion of selected tomography picks along line 16 that are located within a 5km radius of the station 21. The figure 2 is a representation of all the tomography shots and the respective station locations near the Orca Volcano. Another German OBS station will be added to this in the future as BRA 28, and will be located south of Station BRA 27.

In order to pick the water waves in these station on the shots that were selected for each station. The parameters used in the tlPicker menu are shown in Figure 3.

The figure 4 below shows this set of water waves generated along Line 16 station 21 as a record section. Each onset of the water waves is denoted by a red line picked by setting the wiggle option to -1 within tlPicker. To generate this record plot, a clip of 1 was used with 1e-05 scale on the channel 3. Using tlPicker, the water wave arrivals were picked at ranges of ≤5 km for each station and used within the inversion code, ‘Obsloc’. Obsloc is a function that could relocated the positioning of the OBSs given the Shot positions, and multiple water wave arrival times to a station.

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*Figure 3: tlPicker Menu showing filter and plotting parameters*

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Figure 4: Water wave picked on a record section of the station, BRA21

When visualizing which events are recorded in multiple station the figure 5 below shows that a significant portion of tomography shots are recorded in 3 or more stations

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*Figure 5: Number of stations recording the same event*

This above figure could be further visualized in a form of a map. Looking at this figure 6, it is evident that most of the stations near the central portion of the shot geometry has 3 or more stations recording the same shot.

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Figure 6: tomography shots that were detected by less than 3 stations, 3 stations, and more than 3 stations

The inversion requires a velocity or a velocity profile. The script TTtables\_simple was used to create a constant velocity profile and the mat file it generated was used for the inversion.

The figure 7 is a representation of how the RMS residuals of change in each station for each constant velocity (1445-1465 m/s) within the inversion. The labels indicate the velocity at its local minimum. These best velocity values range from 1453 to 1459 m/s. Within the overall inversion at different constant velocities, the velocity that yielded the best overall lowest RMS residuals was at 1456 m/s.

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*Figure 7: Velocity with the minimum RMS residuals for each station*

The figures 8 above are showing how the best velocity (Determined by Figure E) varies through the station geometry. While we initially hypothesized that the best velocity might vary from east to west, the figure 8 debunks this to show that the velocity varies pretty randomly across stations.

Further exploration of these best velocity values by station indicate that, for the best velocity values ranging from 1453 to 1459 m/s, influences the inverted depth to only change by 24 m between end members. This is showcased in one of the stations: BRA 13 in figure 9. Such that, it was decided to use the overall best velocity for the inversion, 1456 m/s as the velocity to determine the relocated station locations.

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*Figure 8: Best velocity variability by station*

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*Figure 9: Inverted Depth of Station BRA13 at various velocities*

When performing the inversion with the constant velocity of 1456m/s, the total RMS residuals are minimized over 5 iterations. This iterative approach to resolving the station locations is necessary because of the station location is a nonlinear inverse problem. Figure 10 represents this procedure and showcase how most minimization occurs within the first two iterations of the inversion.

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*Figure 10: Iteration misfit when inverting for all stations*

The Figure 11 is the result of the inversion performed on all stations.

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Figure 11: Difference between the original XYZ location and it’s corresponding inverted XYZ location

This figure 11 shows the variability in the x, y, z directions in each station with respect to its assumed original station position. While the station Index 12 shows significant variability in the x, y, z direction, this station: BRA25 was found to be relocated correctly when comparing the relocated depths to bathymetric depths. Most significant jump in depth, observed in station 25 is found to be located on the north eastern slope of the caldera. With even a small lateral variation, the depth is expected to change much more.

Station indexes range from 1 to 14, corresponds to the following stations:

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| index | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Station | BRA13 | BRA14 | BRA15 | BRA16 | BRA18 | BRA19 | BRA20 |
| index | 8 | 9 | 10 | 11 | 12 | 13 | 14 |
| Station | BRA21 | BRA22 | BRA23 | BRA24 | BRA25 | BRA26 | BRA27 |

As shown in Figure 12, the RMS residuals observed in each station is less than 8x10-3 seconds. The Highest residual was recorded in index 14: Station BRA 27.

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*Figure 12: RMS residuals by station resulted from the inversion*

The figure 13 is a Misfit histogram between the Observed Travel Time and the Predicted travel time for each event used in the inversion. From this figure it can be noted that the errors are gaussian and there are some outliers within the data that needs to be evaluated.

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*Figure 13: Misfit histogram of all travel times used in the inversion*

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*Figure 14: Travel Time Misfits of all the stations*

Figure 14 denotes the misfit (Observed arrival times – predicted arrival times) . Here we can see that certain stations contain 4 or 6 times the picking uncertainty. This means that either these picks are bad or there is some other error associated with the data. So, it’s important to check what these water wave picks look like.

This figure shows a sloped misfit. Further investigation showed that the misfits along a line increased towards the tomography shot having the shortest distance between itself and the station.

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Figure 15: Inverted XY locations and their original Inverted locations along with all the tomography shots used

Figures 15 shows how the initial position of the station changed to the final location iteratively. Figure P shows the relocation in the XY plane. The events were denoted as red dots. Final iteration is denoted by red squares and the blue squares are the initial station location before the inversion.

For the purpose of determine how well the inversion is doing in its ability to relocate the stations, a comparison of depths of stations between the inverted depths and bathymetric depths was produced. The figure 16 was produced by extracting the Bathymetric data using gmt and plotting it along with the inverted depth data for comparison.

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Figure 16: Inverted Depth vs Bathymetric Depths for Inverted Station Location