Updated March 30th, 2022

Seismic velocity models offshore Eastern North American Margin

Dataset Authors

Brandon Shuck[1], Harm Van Avendonk[2], Anne Bécel[1]

[1] Lamont-Doherty Earth Observatory, Columbia University, Palisades, NY, USA
[2] Institute for Geophysics, University of Texas at Austin, Austin, TX, USA
Contact bshuck@ldeo.columbia.edu for questions related to this dataset.

Summary

The following dataset contains seismic velocity models from offshore eastern United States. These velocity models were constrained by traveltime tomography of active-source Ocean Bottom Seismometers data along three profiles from the Eastern North American Margin Community Seismic Experiment (ENAM CSE). P-wave velocity models for Line 1, Line 2, and Line 3 are included as well as a S-wave velocity model for Line 3. Collectively, these tomographic velocity images reveal subsurface properties and information on the ancient rifting event between eastern North America and west Africa during the breakup of Pangea and formation of the Central Atlantic ocean, but may also be relevant for other studies such as modern processes along the margin.

Contents in this archive

Seismic velocity grids

Velocity models are exported every 180 meters in the horizontal X direction, and every 90 meters in the vertical Z direction.

Columns are: X-coordinate (km), Z-coordinate (km), Vp (km/s)

The X-coordinate of Line 1 and Lines 2 models is zero at the coastline. Model Z-coordinates are positive and increasing with depth. Line 1 and Line 2 models start at one kilometer above sea level (-1.0) due to the landward extension of the profiles; however, the onshore domain is not shown or archived here due to poor ray coverage.

ENAMcse_MGL1408_Line1obs_Vp.dat ⟶ Line 1 P-wave velocity model
ENAMcse_MGL1408_Line2obs_Vp.dat ⟶ Line 2 P-wave velocity model
ENAMcse_MGL1408_Line3obs_Vp.dat ⟶ Line 3 P-wave velocity model
ENAMcse_MGL1408_Line3obs_Vs.dat ⟶ Line 3 S-wave velocity model

Columns are: X-coordinate (km), Z-coordinate (km), Vs (km/s). This velocity model was produced by traveltime inversion of shear-waves that were converted at the seafloor. Note that these phases traveled as P-waves throughout the water column, hence there is a corresponding P-wave velocity of ~1.5 km/s above the seafloor.

Interfaces in velocity models

These files describe the coordinates of layers within the velocity models. Each model consists of four layers (top to bottom): siliciclastic sediments, carbonaceous sediments, crust, mantle. Layer coordinates are exported every 180 meters in the X direction.

Columns are: Layer ID, X-coordinate (km), Z-coordinate (km)

Layer ID: 1 = seafloor, 2 = top of carbonates, 3 = top of basement, 4 = Moho

ENAMcse_MGL1408_Line1obs_Vp_Zlyrs.dat ⟶ Line 1 P-wave model layers
ENAMcse_MGL1408_Line2obs_Vp_Zlyrs.dat ⟶ Line 2 P-wave model layers
ENAMcse_MGL1408_Line3obs_Vp_Zlyrs.dat ⟶ Line 3 P-wave model layers
ENAMcse_MGL1408_Line3obs_Vs_Zlyrs.dat ⟶ Line 3 S-wave model layers

Velocity model geometry files

These files describe the spatial link between geographic coordinates and cartesian coordinates of the velocity models.

Columns are: Longitude (dd), Latitude (dd), X-coordinate (km), Water depth (km)

ENAMcse_MGL1408_Line1obs_Vp_llxz.dat ⟶ Line 1 P-wave model coordinates
ENAMcse_MGL1408_Line2obs_Vp_llxz.dat ⟶ Line 2 P-wave model coordinates
ENAMcse_MGL1408_Line3obs_Vp_llxz.dat ⟶ Line 3 P-wave model coordinates

Velocity model images

These files are images of each seismic velocity model and corresponding ray coverage. The top panels show the Derivate Weight Sum (DWS) of each model, which is a measure of ray density in the model's grid space. Likewise, the density of bounce points on each reflecting boundary are shown by the relative size of black circles. DWS can be used to assess areas of poor ray coverage and hence use caution when interpreting velocities or layer boundary depths in these domains. Here, the base10 logarithm of DWS for each model is taken and the corresponding colormap and size of circles along boundaries are normalized to span the minimum and maximum of these values. This normalization is done for each individual model – thus, the plots show relative areas of good and bad ray coverage within a single model but should not be used to quantitatively compare ray density from model to model. Velocity models are plotted with 1 km/s contours.

ENAMcse_MGL1408_Line1obs_Vp_DWS.png ⟶ Line 1 P-wave model image
ENAMcse_MGL1408_Line2obs_Vp_DWS.png ⟶ Line 2 P-wave model image
ENAMcse_MGL1408_Line3obs_Vp_DWS.png ⟶ Line 3 P-wave model image
ENAMcse_MGL1408_Line3obs_Vs_DWS.png ⟶ Line 3 S-wave model image

Citation information

Please cite the following article when using these velocity models:

Shuck, B. D., Van Avendonk, H. J. A., & Bécel, A. (2019). The role of mantle melts in the transition from rifting to seafloor spreading offshore eastern North America. *Earth and Planetary Science Letters*, 525, 115756. https://doi.org/10.1016/j.epsl.2019.115756

Cruise information

The ENAM CSE project acquired both onshore and offshore seismic data centered on Cape Hatteras, North Carolina. The experiment was funded by the National Science Foundation as part of the Geodynamic Processes at Rifting and Subducting Margins (GeoPRISMS) program, where the community selected the ENAM as a primary site to investigate continental rifting processes. Active-source seismic data from the ENAM CSE included four major offshore wide-angle seismic profiles acquired with an airgun source and Short-Period Ocean Bottom Seismometers (SPOBS). Two of the four major profiles, Lines 1 and 2, are oriented perpendicular to the margin and span from the continental shelf to oceanic abyssal plain and were extended into the proximal onshore domain with deployments of short-period seismometers. The offshore active-source data were collected in a two-ship experiment, with SPOBS deployed and recovered by the R/V Endeavor, while the R/V Marcus G. Langseth provided airgun shots.

A summary of the ENAM CSE can be found in the following citation:

Lynner, C., Van Avendonk, H. J. A., Bécel, A., Christeson, G. L., Dugan, B., Gaherty, J. B., Harder, S., Hornbach, M. J., Lizarralde, D., Long, M. D., Magnani, M. B., Shillington, D. J., Aderhold, K., Eilon, Z. C., & Wagner, L. S. (2020). The eastern North American margin community seismic experiment: An amphibious active-and passive-source dataset. *Seismological research letters*, 91(1), 533-540. https://doi.org/10.1785/0220190142

Multichannel seismic (MCS), Ocean Bottom Seismometer (OBS), bathymetry, gravity, and magnetic data from the ENAM CSE are publicly available from the Marine Geoscience Data System (MGDS): https://www.marine-geo.org/tools/entry/MGL1408

The MGL1408 cruise report is also linked on the MGDS page: https://www.marine-geo.org/tools/search/Document_Accept.php?client=DataLink&doc_uid=3140&entry_id=MGL1408

Raw and processed OBS datasets should be cited as follows:

Van Avendonk H. Dugan B. Lizarralde D. Christeson G. Shillington D. Bécel A. Hornbach M. Long M. Harder S., and Magnani M. B., et al. 2014. Ocean Bottom Seismometer Data Off North Carolina and Virginia, Acquired during R/V Endeavor Expedition EN546 (2014) as Part of the Eastern North America Community Seismic Experiment (ENAM) , Academic Seismic Portal at UTIG, Marine Geoscience Data System, doi: https://doi.org/10.1594/IEDA/500014

Van Avendonk H. Dugan B. Magnani M. B. Lizarralde D. Christeson G. Shillington D. Bécel A. Hornbach M. Long M., and Harder S., et al. 2015. Ocean Bottom Seismometer Data, Updated with Relocated Instrument Coordinates, off North Carolina and Virginia, Acquired during R/V Endeavor Expedition EN546 (2014) as Part of the Eastern North America Community Seismic Experiment (ENAM) ,

Academic Seismic Portal at UTIG, Marine Geoscience Data System, doi: https://doi.org/10.1594/IEDA/500017

Data analysis

See Shuck et al. (2019) for a full description of seismic data interpretation, integration, and inversion methods to produce these velocity models. Short-period four-component OBSs spaced at approximately 15 km along three transects recorded seismic sources produced by the Langseth with an airgun array of 6,600 in^3 volume at 225 m intervals. Here we archive compressional- (Vp) and shear-wave (Vs) velocity models along three key transects: Two dip lines (Line 1 and Line 2), and one margin-parallel line along the Blake Spur Magnetic Anomaly (Line 3). Seven distinct wide-angle seismic phases, including refractions and reflections, were identified on OBS records along the ENAM CSE lines.

We implemented a four-layer tomographic model with (top to bottom) siliciclastic sediments, carbonaceous sediments, crust, and mantle. The seafloor surface was derived from the global ETOPO bathymetry grid. The top of carbonates and basement surfaces were picked on coincident multi-channel seismic reflection data and used to constrain these interfaces in the models. Additionally, Air-gun shots recorded on land seismometers provided some constraints on the deep structure beneath the continental shelf, but still have limited ray coverage onshore, so we only show the offshore domain of Line 1 and Line 2 starting at the shoreline. On ENAM Line 3, shear- wave arrivals converted at the seafloor were clearly identified on transverse components. We performed a tomographic inversion of all travel-time data using the method described by Van Avendonk et al. (2004) to simultaneously constrain layer thickness and seismic velocities on each of the transects. Inversions iteratively updated the models and minimized the traveltime misfit of all phases until $\chi^2 \approx 1$ and RMS $\approx$ 100 ms.

To constrain shear-wave velocities of the crust and mantle along Line 3, we converted the final P-wave model and traced shear-wave crustal refractions (Sg) through the crust to test various Vp/Vs ratios for the overlaying sedimentary layers. A best fitting Vp/Vs ratio of 2.22 was used for the two sedimentary layers, while initial Vp/Vs ratios of 1.758 and 1.787 were used to convert P-wave velocities for the crust and mantle, respectively. Inversion of converted shear-waves turning in the crust (Sg), reflecting off the Moho (SmS), and turning in the upper mantle (Sn) were used to constrain the Vs structure of the crust and mantle. In these iterative inversions, we kept all model boundaries fixed from the final P-wave model and only updated Vs structure of the crust and mantle.