Uncovering Deep Earth: Analyzing Pg and Pn velocities across the Appalachian region to investigate the lithosphere structure

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Abstract

The Earth's interior consists of the crust, mantle, and core. Distinctive features that make the Earth unique are five central systems or spheres: the geosphere, biosphere, cryosphere, atmosphere, and hydrosphere- these systems overlap and interact in complex ways that are not visible to the human eye. Topographic features are characteristics of the Earth's surface, such as volcanoes, faults, and mountains, which are visible plate boundaries or physical expressions of plate tectonics. As continental plates move toward or slip past each other, this movement causes pressure to build up at their boundaries, resulting in earthquakes. The area where two plates slip past each other is referred to as a fault. The plate boundaries, or the edges of the plates, get stuck on a moving plate, and when the moving plate overcomes the friction, this energy radiates and releases seismic waves. Seismic waves such as P-waves, S-waves, and surface waves, propagate in different directions and exhibit distinct motions. Seismic imaging is used to detect tectonic activity, including rifting, orogenesis, subduction, and terrane accretion.

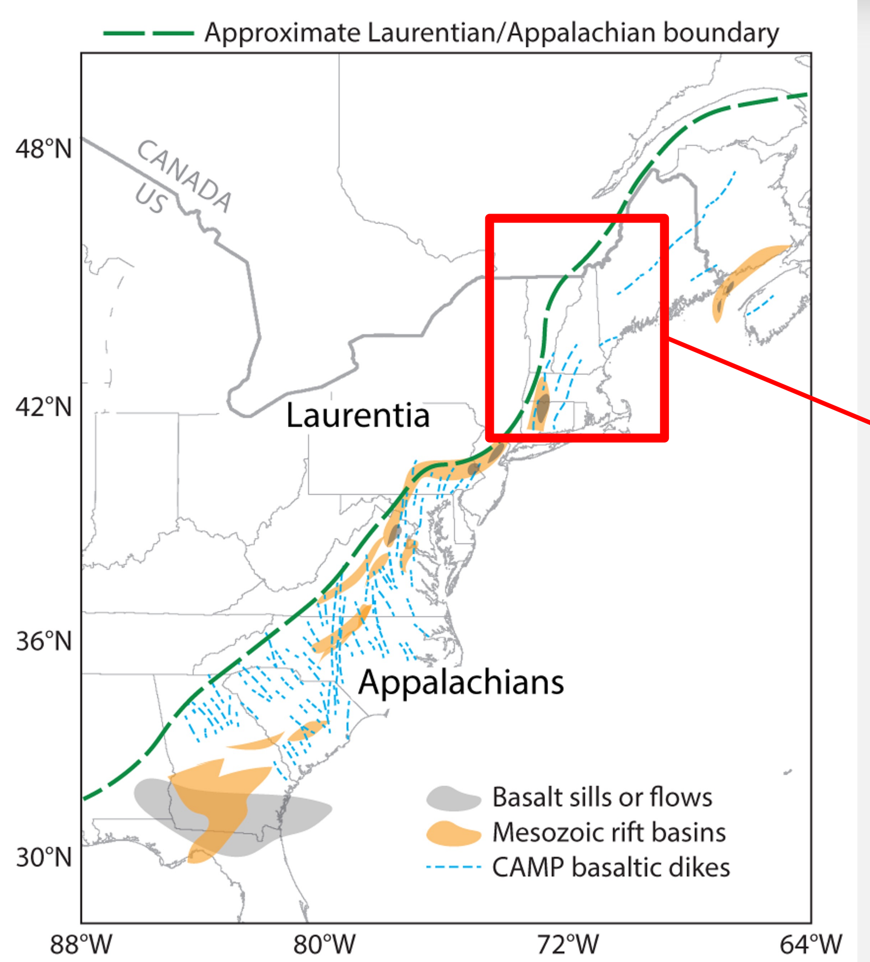
In this study, we observed different Pg (Earth's crust) and Pn (Earth's upper mantle) arrival times velocities to investigate the lithosphere beneath the New England Appalachian orogen. The data analysis consisted of regional earthquakes recorded from various azimuths and a wide range of seismic stations. Our current findings and previous results reveal discontinuities that are consistent with a suture, a boundary where two terranes were held together, as indicated by variations in crustal thickness and the Moho step —the boundary between Earth's crust and upper mantle. Understanding the eastern North American margin (ENAM) will reveal insights into geophysical imaging that explain how the lithosphere is structured and how it has evolved. In the future, we hope to confirm the suture zone by deploying multiple broadband seismometers near the discontinuity, incorporating geochronological dating and radiometric dating.

Introduction to NEST

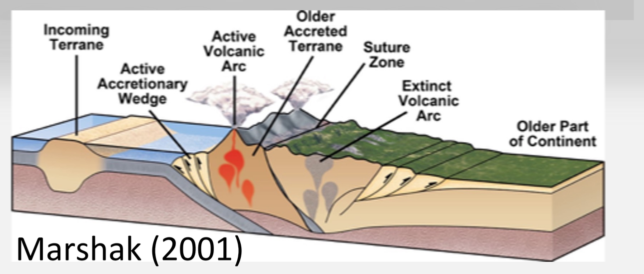
The defining feature of Eastern North American geology is the near north-south trending surficial expression of the Appalachian Mountains which range from Newfoundland to Alabama. Formed by multiple episodes of accretion and subsequent rifting over the last ~0.5 Ga, they record multiple Wilson Cycles and form a natural laboratory for study. Distinct tectonic terranes (i.e. Avalon, Gander, and the more recently proposed Moretown) in this region are defined by surficial observations (geology, geochronology, geochemistry) while their distinctions at depth remain unclear.

Several previous studies (Cong et al., 2018; 2020; Luo et al., 2021; 2022; and Acre-Masis et al., 2023; Bourke et al., 2025) have observed a clear crustal offset (Moho-Step) across the suture between Laurentia and Appalachian terranes, suggesting the border of these ancient units consists of a crustal scale boundary across most of Eastern North America.

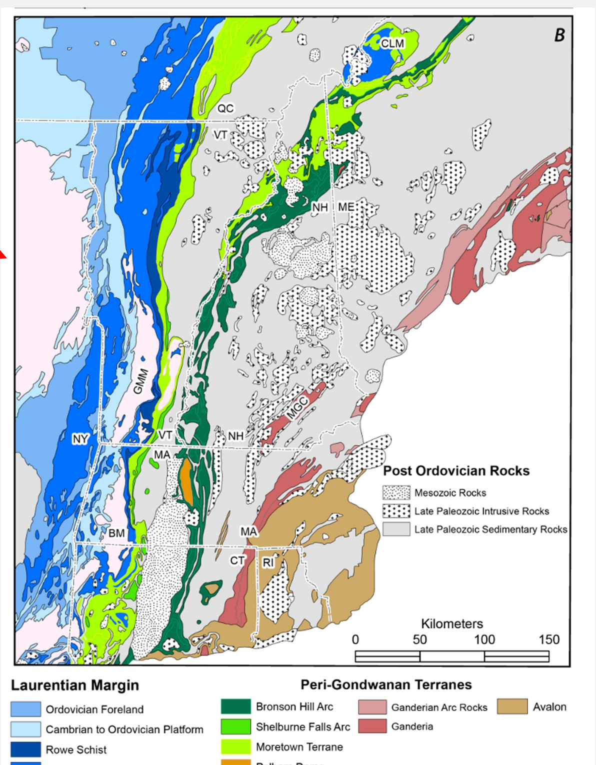
The NEST: New England Seismic Transect project aims to illuminate the crust and upper mantle structure of New England.



(Long, 2024)

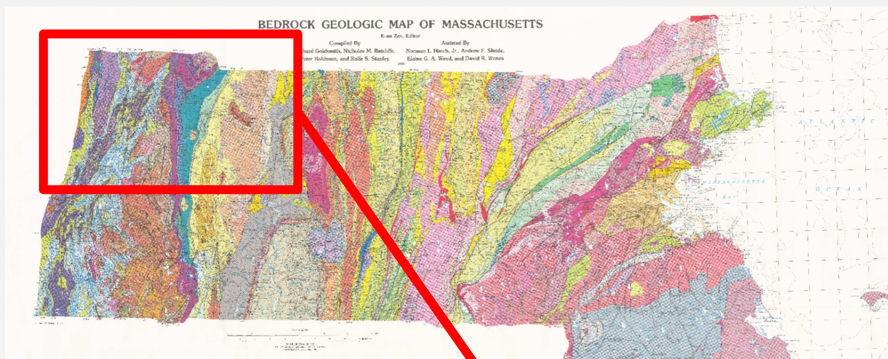


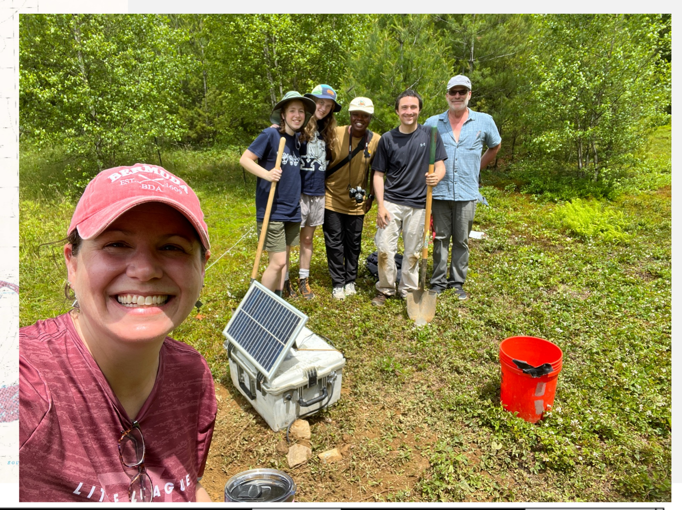
Marshak (2001)

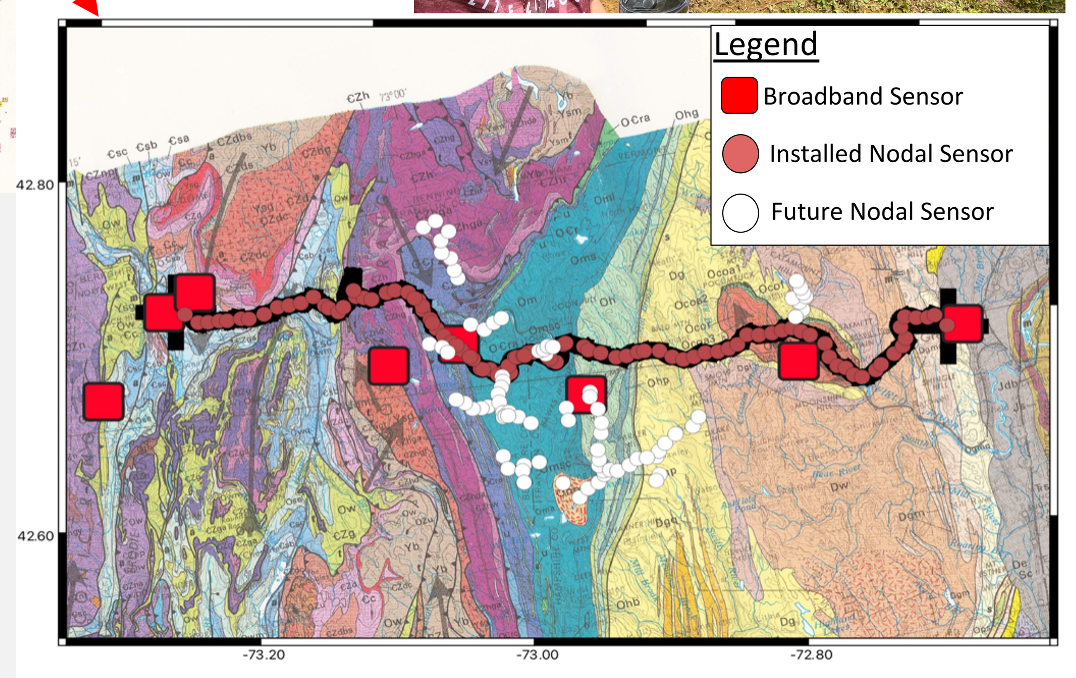


Karabinos et al. (2017)

Field Work for NEST





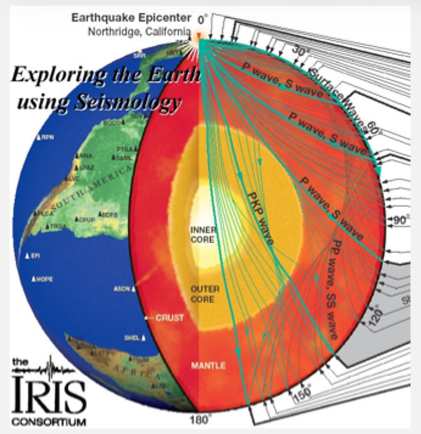


One hundred seven Smart Solo IGU-16HR-3C nodes were deployed along the east-west transect across Massachusetts. This route is approximately 50 kilometers, designed to intersect key geologic terranes and fault zones of the Appalachian orogen. There were approximately 500 meters between each seismometer. Heavily saturated units recorded highly detailed geophysical data, focusing on precision while leaving a small footprint. Each node, installed with an auger, is aligned with True North and records ground motion by converting voltage into digital signals using an Analog-to-Digital Converter (ADC). We deployed Broadband and Nodal Seismic sensors along the transect. The broadband sensors can detect most seismic waves from earthquakes anywhere in the world. The nodal sensors are less sensitive, however when deployed in mass they overcome these obstacles. Across this transect, we investigate the processes that shaped the New England continental lithosphere, the Appalachian orogens, and whether deeper structures reveal past tectonic activity.

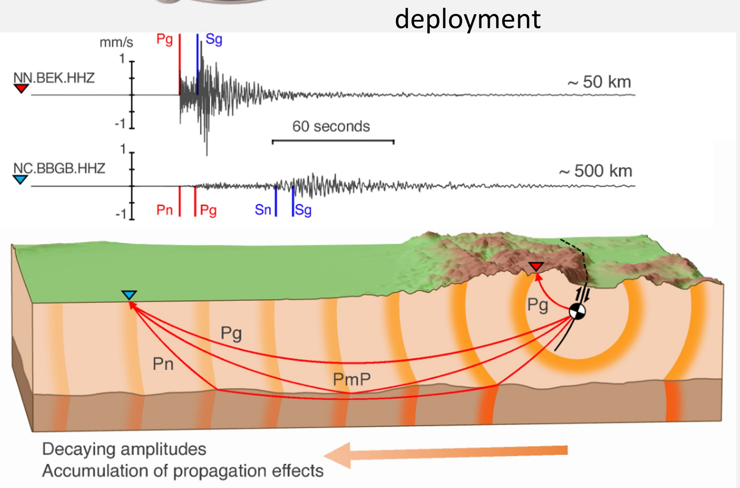
Above: IGU-16HR-3C nodal sensor at site 35 in Charlemont, MA. This sensor can record most large earthquakes anywhere in the world

Left: Broadband Trillium Horizon seismic sensor. This sensor can record all large earthquakes anywhere in the world and are used as anchor points along the nodal deployment

EarthScope Consortium



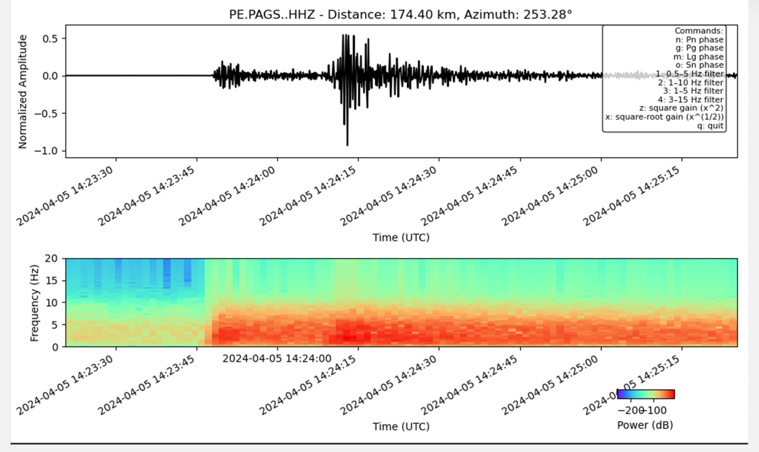
This image highlights teleseismic wave propagation from an earthquake and travel throughout the Earth's interior.

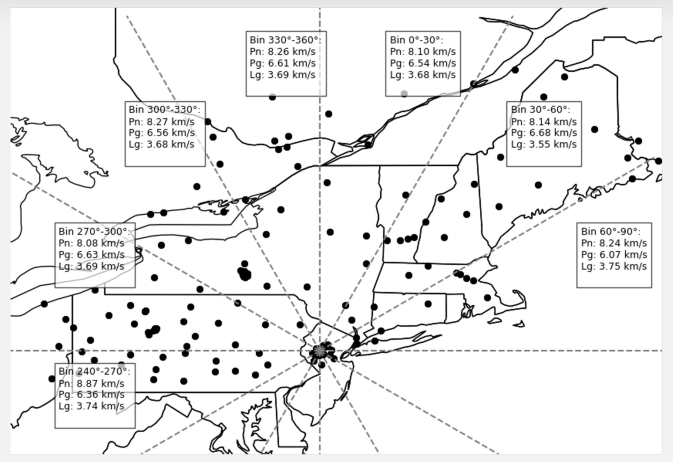


This image highlights regional seismic wave propagation from an local earthquake.

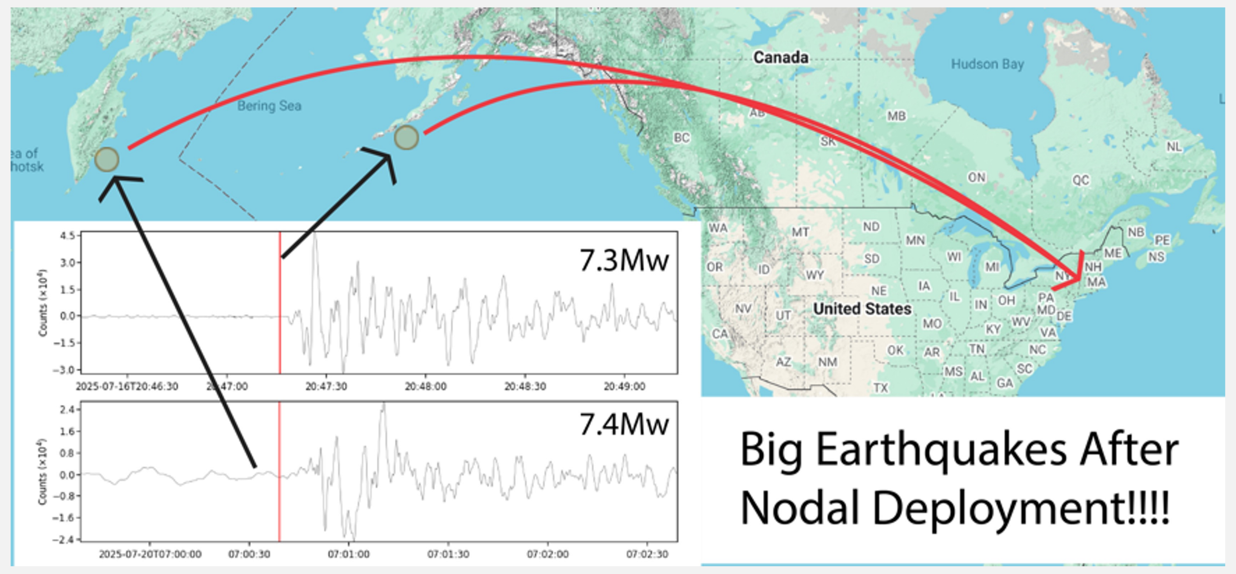
Results/Discussion

Our findings reveal a suture between Laurentia and the various accreted Appalachian terraces, which correlates to variations in crustal thickness and the crust-mantle boundary identified by Pg and Pn velocities in the New England region. The presence of the Moho signifies that the eastern New England Margin (ENAM) was an active margin in the past, and these geologic imprints indicate that past tectonic activities were recorded.





Future Directions



After the extensive nodal deployment, along the east-west transect across Massachusetts. The seismometers detected a 7.3Mw earthquake in Sand Point, Alaska, on July 16, 2025, 20:37:39 (UTC), which allows for a seismic wave analysis, mapping crustal thickness, and discovering potential discontinuities in the continental lithosphere.

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