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Key Points:
- The crustal thickness shows a complicated distribution pattern both along and across the orogenic strike in the northern Appalachians
- A distinct subrectangular downward deflection of the Moho correlates with low Bouguer gravity anomaly in northern New Hampshire and western Maine
- The spatial correlation observed between Moho depth variations and interpreted tectonic units provides constraints on the depth extent of the tectonic boundaries within the crust

Supporting Information:
- Supporting Information S1
- Table S1

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Crustal Thickness Variation in the Northern Appalachian Mountains: Implications for the Geometry of 3-D Tectonic Boundaries Within the Crust

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Abstract Teleseismic receiver functions were calculated to image the Moho geometry in the northern Appalachian Mountains in order to explore crustal thickness variations and possible linkages with tectonic units. Waveforms from 1995 to 2016 were analyzed for a total of ~ 200 broadband seismic stations, yielding a well-distributed data set with high lateral resolution. Consistent *P*-to-*S* phases converted at the Moho can be clearly observed. The Moho depth increases from the coastal plain northwestward to the Appalachian Plateau, with a sharp east-west gradient in southern New England. A distinct subrectangular downward deflection of the Moho is imaged in northern New Hampshire and western Maine. There is a spatial correlation observed between Moho depth variations and the NE-SW trending Appalachian orogenic strike. Variations of crustal thickness along and across the orogenic strike provide insights into the formation and modification of the crust during and after the major Appalachian orogenic events.

Plain Language Summary The Wilson tectonic cycle is one of the most fundamental processes leading to growth and modification of continental crust on Earth. Eastern North America provides a complete record of the eastward growth of the continent and has been used as a type section and model of plate tectonics for decades. Although the surface boundaries between former continental fragments are increasingly well known, a question persists about the timing and processes involved with the growth and stabilization of the continental crust. In this study, we provide high-resolution crustal thickness variations in New York and New England, in order to identify the boundaries between tectonic units within the crust. The abundance of broadband seismic stations has significantly increased in the last few years, including the EarthScope Transportable Array and many long-running stations. The crust thickness demonstrates a much sharper east-west gradient in southern New England than in northern New England. A distinct subrectangular downward deflection of the crust is imaged in northern New Hampshire and western Maine. Variations of the crustal thickness along and across the orogenic strike provide insights into the formation and modification of the crust during and after the major Appalachian orogenic events.

1. Introduction

The northern Appalachian Mountains include a series of iconic orogenic belts, which have recorded two complete Wilson Cycles from the assembly of the (circa 1000 Ma) supercontinent Rodinia to the formation of the modern Atlantic Ocean (Heaman & Kjarsgaard, 2000; Thomas, 2006). The first Wilson Cycle began with the assembly of Rodinia, which may have established the fundamental oroclinal geometry of the subsequent collisional margin (Rivers, 2015; Thomas, 1977, 2006). The breakup of Rodinia opened the Iapetus Ocean by 530 Ma (Thomas, 2006). The second Wilson Cycle started at ~ 480 Ma with a sequence of accretion events involving continental and oceanic terranes (Hatcher, 2010; van Staal et al., 2009). These accreted terranes, from west to east, can be divided into at least three parts (Figure 1): the Taconic belt, a peri-Laurentian element interpreted to have been accreted during the Ordovician Taconic orogeny; the peri-Gondwanan Gander terrane (± Moretown terrane) that occupies a large part of central New England and may have accreted in the Salinic orogeny; and the Avalon terrane, accreted during the Acadian orogeny (Hibbard et al., 2006, 2007; Karabinos et al., 2017). Subsequent collisional events involved the accretion of the Meguma Terrane (outboard of Avalon) and ultimately collision with Gondwana during the Alleghenian orogeny (Domeier, 2016; van Staal et al., 2009). After assembly, several stages of rifting, exhumation, and possibly orogenic collapse ultimately led to the establishment of the modern passive continental margin by ~ 180 Ma (e.g., Dorais et al., 2012; Hatcher, 2010; van Staal et al., 2009).

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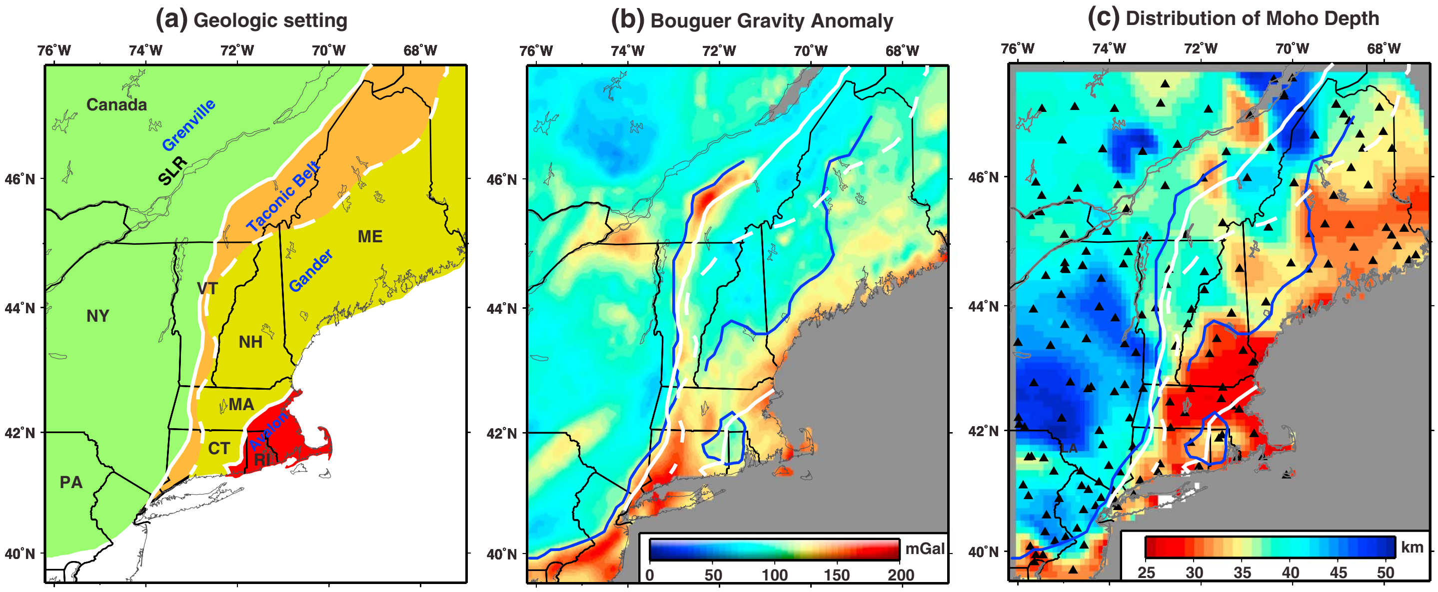

Figure 1. (a) Geological map showing the major tectonic units in the northern Appalachian Mountains, modified after the lithotectonic map of the Appalachian orogen by Hibbard et al. (2006) and the United States Geological Survey basement domain map (http://mrdata.usgs.gov/ds-898/). SLR = St. Lawrence River. Black lines mark state boundaries. The white solid lines mark the interpreted Grenville-Taconic and Gander-Avalon boundaries, and the white dashed line is the proposed eastern boundary of Taconic belt by Hibbard et al. (2006) and Karabinos et al. (2017). (b) Distribution of Bouguer gravity anomalies from Bonvalot et al. (2012). (c) Distribution of the Moho depth (in kilometers) extracted from the common conversion point stacking. Black triangles mark the broadband seismic stations used in the calculation of receiver functions. The solid blue lines in Figures 1b and 1c highlight the sharp gradient in Bouguer gravity discussed in the text.

Geological and geophysical studies have been done to characterize the three-dimensional geometry of the major tectonic units in the Appalachian orogenic belt. The lithotectonic map by Hibbard et al. (2006) provides a first-order compilation of the configuration of tectonic terranes and terrane boundaries in New England and their correlation with the northern and Canadian Appalachian Mountains. The crustal structure has been studied by seismic refraction and reflection methods (e.g., Ando et al., 1984; Hennet et al., 1991; Hughes & Luetgert, 1991, 1992), and by passive seismic methods including receiver function (RF) analysis, wave propagation, tomographic imaging, and surface wave dispersion analysis (e.g., Levin et al., 1995, 2017; Li et al., 2002; Shalev et al., 1991; Taylor & Toksöz, 1982; Viegas et al., 2010). However, due to the relatively sparse station coverage, none of these previous studies was able to characterize the regional-scale crustal seismic structure of the northern Appalachian region. Debates remain about the subsurface extent of the accreted terranes. For example, how does the character of the terranes change along and across orogenic strike, and to what degree do geologically defined surface terranes correlate with variations of seismically defined crustal structure? To answer these questions, a well-constrained three-dimensional crustal model is needed.

The Earthscope Transportable Array (IRIS Transportable Array, 2003) deployment in eastern North America in 2013–2015, retention of many sites by the Central and Eastern United States (UC San Diego, 2013), together with many other regional seismic networks (see supporting information), has significantly increased the spatial density of broadband observations. This provides a new opportunity to investigate the crustal and upper mantle structure. Here we use teleseismic *P* wave RFs to explore the crustal thickness variation from the Atlantic coast to the Grenville Province. The goal of this study is to constrain the geometry of the Moho and crustal thickness of New England, and ultimately to improve our understanding of the impact of past tectonic events on the crustal structure.

2. Data and Methods

A total of 87 permanent and 109 temporary broadband seismic stations have been used in this study (see the station distribution in Figures 1c and S1). Descriptions of the various seismic networks are provided in the supporting information. The well-distributed coverage of the broadband seismic stations makes it feasible to obtain a regional-scale Moho geometry using teleseismic RFs. The waveform data were collected from the Incorporated Research Institutions for Seismology Data Management Center for a total of 688 high-quality earthquake events from 1995 to 2016 with body wave magnitude larger than 5.4 at epicentral distance of 30°–95°. The selected teleseismic events demonstrate good back azimuthal coverage from the NW and SW quadrants for the direct *P* waves (Figure S2), although there are fewer events from the NE and SE quadrants.

The *P* wave RFs were obtained using the water level frequency-domain deconvolution method (Ammon, 1991; Langston, 1979; see supporting information). We implemented three steps to evaluate and control the quality of the observed radial-component RFs, based on the primary P_ms phases. First, we visually inspected all of the resulting RFs and manually selected only RFs with signal-to-noise ratios equal to or greater than 3. The signal is referred to as the maximum positive amplitude within the 2–7 s window after the direct *P* arrival, and the noise is defined as the standard deviation of the 2–10 s waveforms prior to *P* arrival (see definition in Figure S3). Second, for each station, data were evaluated to insure that the pattern of the P_ms phase is consistent within similar back azimuth directions. Third, selected RFs were filtered within multiple frequency bands, ranging from 0.05–0.75 Hz and 0.1–1.0 Hz to 0.2–1.2 Hz, to check the stability of the P_ms phases. In total, we selected 5,875 RFs. Most long-running stations record high-quality RFs with event numbers ranging from 20 to 190 (Figure S4 and Table S1). Some stations, such as LD.PTNY, LD.CFNY, and LD.BNY, have only been operating in recent years, resulting in fewer events selected. The number of RFs for the temporary broadband stations varies within a range of 2–60 (see a detailed description in Table S1), depending on the operation duration and the data quality. We excluded three EarthScope Transportable Array stations, D62A, E59A, and F62A, due to the poor quality of observed RFs.

The time moveout was applied for the observed RFs with a reference slowness of 0.058 s/km and the IASP91 model in order to correct the impact of ray parameter on P_ms arrival time (Park & Levin, 2016; Yuan et al., 1997; see Figure S5). After moveout corrections, individual radial-component RFs from all back azimuths were stacked to represent the average RF for each station. Although the RF patterns at most stations are back azimuth dependent to some extent (Figures S5–S7), stacking reduces random variations, increases the signal-to-noise ratio, and highlights the primary phases from major velocity discontinuities. We then automatically picked the time of the maximum positive amplitude of the stacked RF within the time window of 2.5–6.5 s as the average P_ms arrival for each site. The uncertainty of the average P_ms arrival is defined as the standard error of the P_ms arrival times from all the RF events at each station.

To illustrate some of the main features of the radial-component RFs, we describe two permanent stations, US.PKME and NE.BRYW, which demonstrate clear and robust P_ms conversions (see Figures S5–S7). For station US.PKME in central Maine, a consistent P_ms signal can be observed at ~ 3.7 s from all directions, indicating a uniform Moho depth beneath this station. Station NE.BRYW located in Rhode Island shows a clear, distinct P_ms arrival at 3.7–4.6 s. We observe an obvious shift of the P_ms signal from ~ 4.0 s for events coming from the north to ~ 4.5 s for events coming from the south. The variation and dependence of the P_ms phase on the back azimuth as observed in this study may be related to a dipping Moho or a combination of dipping Moho and anisotropy. Strong lithospheric anisotropy has been observed beneath eastern North America (e.g., Long et al., 2017; Viegas et al., 2010). However, anisotropy alone would only cause a small amount of time shift of the P_ms phase from different back azimuths (Levin & Park, 1997). Directional variation in P_ms time on the order of 0.5 s likely requires lateral changes in the Moho depth beneath the site, for example, due to systematic dip. Better directional coverage and the use of transverse component RFs can help resolve such complications for individual sites (see examples in Figures S6 and S7). However, this effort falls outside the scope of our regional survey of Moho properties and will be a subject of a follow-up study.

The RFs were converted to depth using the common conversion point stacking method (Hansen & Dueker, 2009; see supporting information), with the three-dimensional reference velocity model of Shen and Ritzwoller (2016). Shen and Ritzwoller (2016) assumed a constant *Vp*/*Vs* ratio of 1.75 in the crust and uppermost mantle. However, the EarthScope Automated Receiver Survey (http://ears.iris.washington.edu) shows that the *Vp*/*Vs* ratio varies within a wide range of 1.6–2.1 in the northeastern United States. In order to examine the impact of *Vp*/*Vs* ratio on Moho depth estimation, we tested simple RF forward models using the method by Frederiksen and Bostock (2000). Given a P_ms arrival time of 4.5 s, the Moho depth would be 35 km for a crustal *Vp*/*Vs* ratio of 1.7 and 39.5 km for a *Vp*/*Vs* ratio of 1.9, respectively (Figure S8). Therefore, a ±4.5 km uncertainty of the Moho depth is expected due to the *Vp*/*Vs* ratio alone. We also

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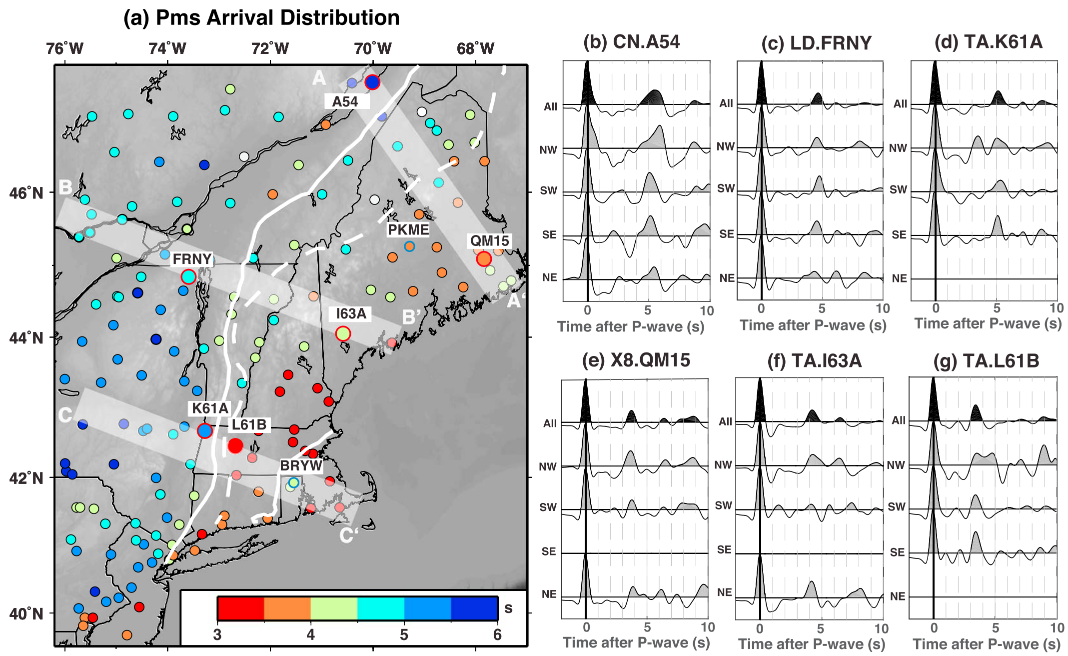

Figure 2. (a) Distribution of P_ms arrival time (in seconds), automatically picked from the stacked radial receiver functions for each seismic station. Warm colors denote relatively smaller P_ms arrivals; cold colors denote larger P_ms arrivals. White dots mark stations with poor-quality data. The three shaded zones are profile locations shown in Figure 3. The larger dots mark the locations of six selected seismic stations with RFs provided in Figures 2b–2g (also shown as yellow dots in Figure 3). (b–g) Representative radial RFs along AA′, BB′, and CC′ showing variation of P_ms arrivals. The RFs are stacked within each quadrant, ranging within 0–90° (NE), 90–180° (SE), 180–270° (SW), and 270–360° (NW), and from all the back azimuth directions. Waveforms are filtered at 0.1–1.2 Hz. RFs = receiver functions.

plotted the piercing point density of the radial-component RFs to demonstrate the spatial resolution of the Moho depth variations (Figure S9). At 20-km depth, the common conversion point stacking mainly samples the structure directly beneath the seismic station. At 40-km depth, the average RF aperture is about 19 km, similar to the results of Rondenay (2009).

3. Results

In this study, we focus on the analysis of the P_ms arrival times extracted from the stacked RFs and the corresponding Moho depth, in order to characterize the variation in crustal thickness in our study area. The P_ms time and Moho depth vary from 3 to 6 s and from 27 to 52 km, respectively (Figures 1c, 2a, and S10). A decrease in crustal thickness can be observed from the Appalachian Plateau toward the Atlantic coast, consistent with previous studies (e.g., Gaherty et al., 2011; Li et al., 2002; Savage et al., 2017; Schmandt et al., 2015; Shen & Ritzwoller, 2016). The lateral distribution of the Moho depth is roughly correlated with the surface topography (Figure S1) and anticorrelated with the Bouguer gravity anomaly (Figure 1b). In general, a lower Bouguer gravity reflects a thicker and/or less dense crust with a higher elevation and vice versa (Li et al., 2003). For example, the thick crust beneath the Appalachian and Laurentian Plateaus correlates with a lower Bouguer gravity anomaly and higher elevation, while the coastal plain has the thinnest crust with a relatively higher Bouguer gravity anomaly and lower elevation.

We selected three profiles (Figure 3) that are nearly perpendicular to the orogenic strike in order to demonstrate the Moho depth variations from the Grenville Province to the accreted terranes along each profile and variations within each tectonic unit by comparing the three profiles. We also provide a NE-SW trending profile in supporting information Figure S11 to show the Moho depth variations along the strike of the Appalachian terranes. Both the P_ms time and the Moho depth demonstrate a much sharper east-west gradient in the southern part (Figure 2; section CC′ in Figure 3) than in the northern part of the region (Figure 2; sections AA′ and BB′ in Figure 3). We observe an offset of the Moho depth of ~ 15 km within a

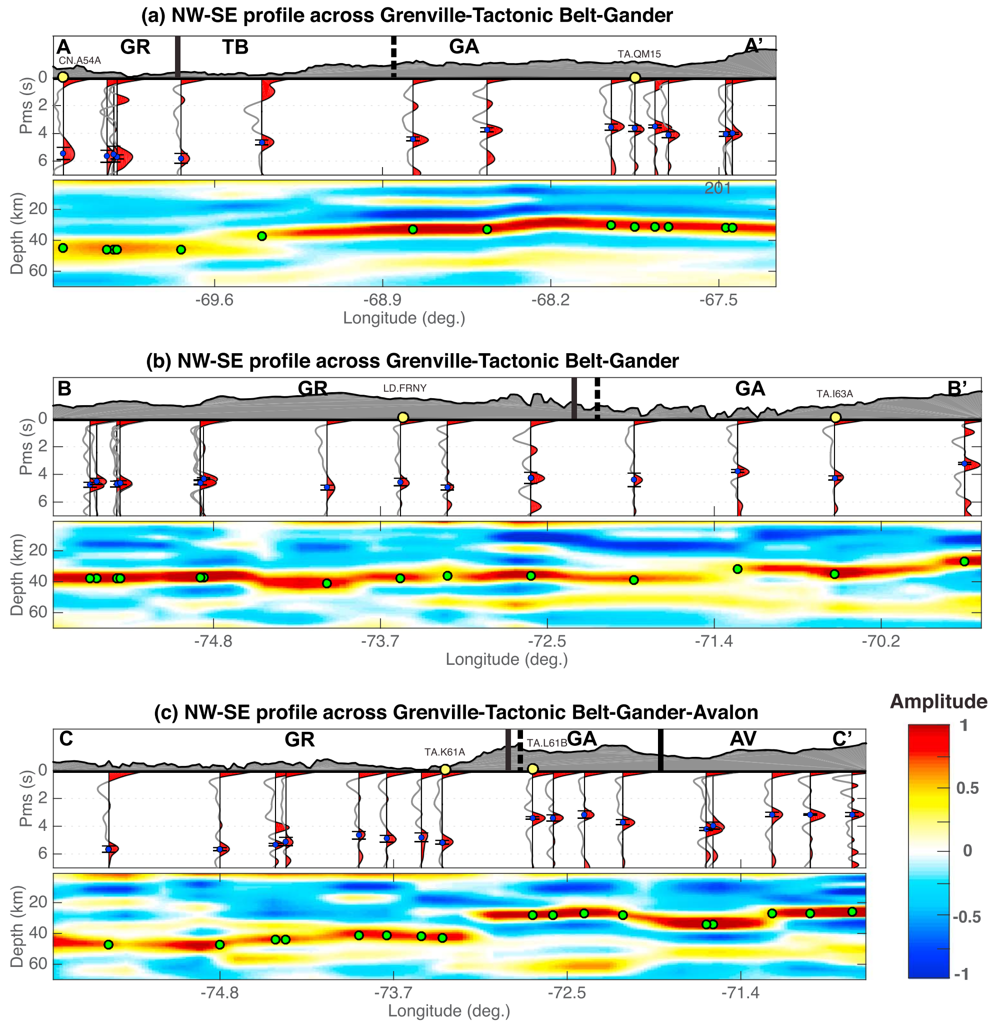

Figure 3. Cross sections of stacked radial receiver functions in the time domain along the three profiles (top) and corresponding depth profiles from the common conversion point stacking (bottom). Grey filled lines represent the Bouguer gravity anomalies and major tectonic units boundaries are marked by solid/dashed black lines above each profile. Blue dots denote the P_ms arrival times with estimated uncertainties, and green dots denote Moho depth. AV = Avalon; GA = Gander; TB = Taconic belt; GR = Grenville Province.

narrow zone in western Connecticut, western Massachusetts, and southern New Hampshire. For example, the Moho depth is about 45 km and 30 km at stations TA.K61A and TA.L61B that are only 70 km apart (section CC′ in Figure 3). Note that the actual offset of the Moho depth may differ slightly as our estimate here is based on the constant *Vp*/*Vs* ratio used for the time-depth conversion. According to the EarthScope Automated Receiver Survey (http://ears.iris.washington.edu), *Vp*/*Vs* values in this region are between 1.7 and 1.85, thus station-to-station variation in Moho depth due to changes in this parameter cannot exceed 4 km. In contrast, the Moho depth varies more gradually beneath the northern part of the study area. The depth increases on the order of 5–10 km, and the transition appears to be more gradational in northern New England and southeastern Canada compared to southern New England (Figures 1c, 2, and S10). For example, between sites CN.A54 and X8.QM15, the Moho depth changes from 47 km to 35 km over a distance of ~300 km.

High lateral resolution derived from the relatively dense coverage of seismic sites highlights small-scale Moho variations. The Moho depth is less than 30 km in southern New England and eastern Maine, and is deeper in northern New Hampshire and western Maine, resulting in a distinct subrectangular downward deflection of the Moho along the Atlantic coast (Figures 1c and 2a). This observed seismic feature is well correlated with the low Bouguer gravity anomaly (Figure 1b). A deepening of the Moho was also indicated

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by previous seismic studies (Hennet et al., 1991; Hughes & Luetgert, 1991; Spencer et al., 1989) but was not well constrained. Local Moho maxima are imaged beneath northern Rhode Island (~ 35 km; see Figures 1c and 3) and northwest of the St. Lawrence River in southeastern Canada (~ 50 km, see Figures 1c and 3; Levin et al., 2017; Petrescu et al., 2016). Beneath northeasternmost Pennsylvania, a localized Moho minimum (~ 35 km) corresponds with a local gravity high.

4. Discussion

Our RF results demonstrate Moho depth variations both across and along the orogenic strike in the northern Appalachian Mountains. Generally, the average P_ms time and Moho depth vary from 4 to 6 s and from 40 to 55 km within the Grenville Province, and 3 to 4.3 s (25 to 35 km) within the accreted terranes (Gander and Avalon; Figures 1c, 2a, and S10). In the southern part, the NE-SW trending distribution of the Moho depth roughly follows the trend of major tectonic boundaries (Hibbard et al., 2006). A clear east-west gradient of Moho depth is observed across the eastern margin of the exposed Grenville (Laurentian) basement (section CC′ in Figure 3). The Moho depth is greater than 45 km in New York within Grenville crust and is less than 30 km across the interpreted Grenville-Taconic Belt boundary (Figures 1c and 2a). In southern New England, the Moho depth decreases from Grenville to Gander by at least 15 km over a relatively small (70 km) horizontal distance (section CC′ in Figure 3). The correspondence between the sharp Moho depth variation and the Bouguer gravity anomaly variation (Figure 1) further supports the presence of such a distinct crustal thickness change. Only subtle Moho variations are seen farther east, across the Gander and Avalon terranes, with a possible exception of a locally deeper Moho in northernmost Rhode Island.

Several key aspects of the dramatic east-to-west step in Moho depth are important for any interpretation. First, the magnitude of the step decreases from southern to northern New England, from ~ 15 km in the south to approximately 5 km in the north. Second, the location of the Moho step progressively diverges from the exposed Grenville basement moving northward, roughly corresponding with the widening of the Appalachian orogen from Massachusetts and Connecticut to northern Maine and southeastern Canada. Interestingly, as the Moho step diverges from the Grenville basement northward, it also diverges from the Bouguer gravity anomaly that defines the Appalachian front (Figure 1b). The divergence is clear despite the fact that, to some extent, the spatial correlation between Moho depth and surface geology in northern New England is complicated by local anomalies (Figure 1c), such as the “subrectangular” downward deflection of the Moho within northern New Hampshire and western Maine (section BB′ in Figure 3).

A variety of tectonic processes, at different times in the geologic history, might have contributed to the steep Moho step in southern New England. The step might represent late Paleozoic differential uplift and exhumation of the orogen (Harrison et al., 1989; Wintsch et al., 2003), or it might reflect changes in crustal thickness due to Mesozoic rifting or underplating (Li et al., 2002). However, the close association of the Moho step with the inferred Grenville-to-accreted-terrane boundary and the parallelism with orogenic strike suggest that it may ultimately be related to the fundamental accretionary boundary between Laurentian basement and the exotic terranes. A study of regional seismic wave propagation from an unusually large earthquake in the Adirondacks (Viegas et al., 2010) suggested that the average *Vp*/*Vs* ratio and the thickness are about 1.73 and 35 km for the Appalachian crust and 1.80 and 42 km for the Grenvillian crust, respectively. Using RF analysis, Levin et al. (2017) also noted systematic differences in *Vp*/*Vs* ratios and crustal thickness values, with Appalachian terranes showing much larger scatter in both parameters, while the region of Grenville Province has a near-uniform *Vp*/*Vs* of ~1.75. The difference in *Vp*/*Vs* ratio and crustal thickness has been directly attributed to the difference in crustal compositions as the Grenvillian crust is more mafic than the Appalachian crust (e.g., Musacchio et al., 1997). Due to the sparse coverage of seismic stations within southwestern New England, it is not possible to trace a crustal boundary through the crust from the surface to the Moho. However, we suggest that the distinct Moho offset in southern New England corresponds with a nearly vertical or steep eastward dipping Grenville-Taconic terrane boundary. Previous seismic reflection/refraction studies also suggested the presence of such an eastward dipping boundary (Ando et al., 1984; Hughes & Luetgert, 1991). It should be noted that postglacial rebound certainly contributed to the long-wavelength Moho variation. However, the magnitude would be on the order of hundreds of meters, rather than kilometers (Sella et al., 2007), and the magnitude would be expected to increase from south to north, opposite from the observed Moho step in New England.

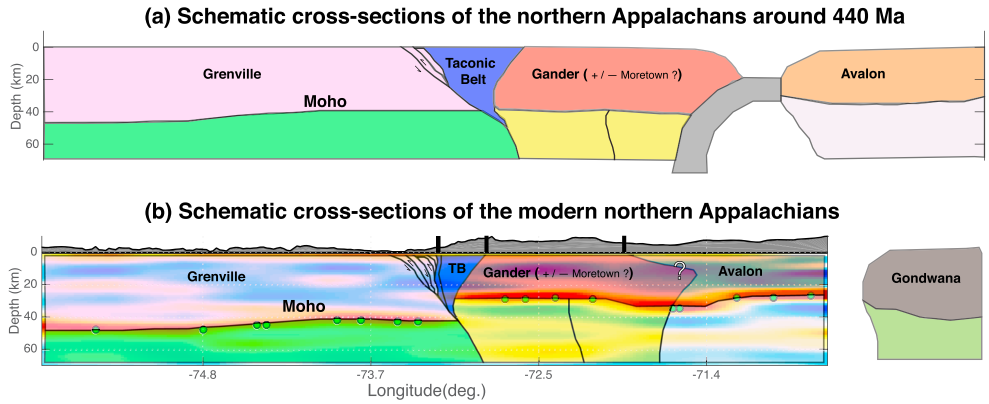

Figure 4. Schematic diagrams illustrating variations of the Moho depth due to Appalachian collisional events along cross section CC′ (Figures 2 and 3), modified after Karabinos et al. (2017). Accretion of Avalon to the Gander terrane (i.e., the Acadian orogeny) is interpreted to have further shortened the Gander and Taconic crust in southern New England. The crustal shortening may have resulted in a nearly vertical or steeply dipping Grenville-Taconic boundary and a narrow surface expression of the Taconic belt in southern New England.

The northward divergence of the Moho step from the Appalachian front and the decrease in the magnitude of the step roughly correspond with the widening of the Appalachian orogeny in northern New England. The narrowness of the orogeny in southern New England, at least to some degree, probably reflects differences in the style and intensity of the overprinting Acadian, post-Acadian, and Alleghenian tectonism in the south relative to the north (Figures 4 and S12). If the Moho step does correspond with the eastern margin of Laurentian crust, it seems likely that the steepness and magnitude of the step in the south may reflect the cumulative effects of subsequent tectonic events. That is, the boundary may have been repeatedly reactivated (and steepened?) during subsequent collisional pulses as has been interpreted in surface geology (Cheney & Brady, 1992; Stanley & Ratcliff, 1985). The boundary in the south may have been further complicated by strike-slip motion during Acadian and post-Acadian tectonism and possibly by differential exhumation and crustal thinning during Mesozoic extension (Thomas, 2006). The lateral offset between the Moho step and the Appalachian front in the north may be a more accurate reflection of the original character of the accretionary boundary. The offset in northern Maine would suggest a dip of approximately 20° to the east, consistent with the hypothesis of an eastward dipping Laurentian margin (van Staal & Barr, 2012).

The lack of a distinct Moho variation between the Avalon and Gander terranes may suggest a similar crustal (and lithospheric) composition between Avalon and Gander than between Grenville basement and accreted terranes (Musacchio et al., 1997; Wintsch et al., 2003). As suggested by many previous studies (e.g., Fischer, 2002; Musacchio et al., 1997; Williams et al., 2014), the crust beneath the Grenville Province may be made denser by composition changes after formation of the continental lithosphere. Alternatively, the Avalon-Gander boundary may have a complex geometry (for example, see Wintsch et al., 2014) that did not (in combination with younger events) result in Moho depth variation. The locally deepened Moho in northernmost Rhode Island may be associated with the boundary, but this cannot be rigorously evaluated at this time due to lack of dense onshore and offshore geophysical data coverage. Other possible candidates for this local Moho deepening would include subsequent partial melting or magmatic underplating related to Mesozoic rifting, which might be supported by the extensive exposure of volcanic rocks in northwestern Rhode Island (Maria & Hermes, 2001).

There are several possible interpretations for the subrectangular Moho depression in northern New Hampshire and western Maine. One possibility is that the anomaly may represent the eastward dipping Grenville/Laurentian margin that is offset approximately 200 km east of the margin to the north or south. The offset would be controlled by early Cambrian transform faults associated with the late Proterozoic rifted margin of Rodinia (Allen et al., 2009; McHone & Butler, 1984; Thomas, 2006). The presence of a Grenvillian geochemical signature in White Mountain plutons of northern New Hampshire might support this hypothesis (Dorais & Paige, 2000). Alternatively, the local Moho may have been modified by younger events, such as magmatic underplating or partial melting in the lower crust during Paleozoic accretion or even Mesozoic rifting (Hughes & Luetgert, 1991; Kuiper, 2016). Local magmatism has been suggested considering the extensive exposure of the White Mountain magma series in northern New Hampshire and southern Maine (Dorais & Paige, 2000).

The origin of crustal thickness variation and Moho steps under New England also has implications for the mantle lithosphere. If the Moho step in southern New England does correspond with the eastern edge of Laurentian crust, then the steep angle of the boundary makes it unlikely that southern New England is underlain by Laurentian mantle lithosphere. Instead, the various terranes may have arrived with their own exotic mantle lithosphere. If so, the modern lithosphere may be quite heterogeneous. Variations of lithospheric thickness and seismic characteristics have been interpreted across the major tectonic boundaries (e.g., Menke et al., 2016). Alternatively, the crustal fragments may have arrived without stable lithosphere, or the lithosphere may have been removed (delaminated) during the accretion process (e.g., Levin et al., 2000). If so, it is possible that the current lithosphere grew after accretion of the peri-Gondwanan terranes. Such a lithosphere would be distinct from that under Laurentia but similar across the accreted terranes.

5. Conclusions

Teleseismic *P* wave RF analysis in the northern Appalachian region has revealed significant Moho depth variations, which are well correlated with the distribution of Bouguer gravity anomalies. We observed a complex Moho depth distribution pattern, both across and along the orogenic strike. In southern New England, a sharp Moho step occurs near the interpreted surface boundary between the Laurentian crust and the accreted terranes. This may indicate a nearly vertical or steeply dipping Laurentian boundary within the crust, probably reflecting the cumulative effects of Paleozoic accretion and crustal shortening events. In contrast, the Moho variation is more gradual in northern New England, in correspondence with the widening of the Appalachian orogen. The lateral offset between the Moho step and the Appalachian front in the north may indicate a generally eastward dipping Laurentian basement. More geophysical and geologic constraints are required to further test our proposed hypotheses.

Acknowledgments
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