ARTICLE IN PRESS
EPSL:12707

Earth and Planetary Science Letters ••• (••••) •••–•••

Contents lists available at ScienceDirect

Earth and Planetary Science Letters

www.elsevier.com/locate/epsl

An introduction to the special issue of Earth and Planetary Science Letters on USArray science

Maureen D. Long[a,*], Alan Levander[b], Peter M. Shearer[c]

[a] Department of Geology and Geophysics, Yale University, New Haven, CT, United States
[b] Department of Earth Science, Rice University, Houston, TX, United States
[c] Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, United States

ARTICLE INFO

Article history:
Accepted 10 June 2014
Available online xxxx
Editor: P. Shearer

Keywords:
USArray
EarthScope
North America
continental dynamics

ABSTRACT

The USArray observatory, a component of the EarthScope science initiative, has provided a geophysical dataset that densely samples the continental US with unprecedented scale and resolution. The major scientific target of the multidisciplinary EarthScope project is an understanding of the structure, dynamics, and evolution of the North American continent, with emphasis on imaging the continental crust and lithosphere as well as illuminating dynamic processes in the deep Earth. This special issue of *Earth and Planetary Science Letters* presents a collection of papers that leverage data from the USArray observatory to provide fundamental insights into Earth's structure and dynamics. Here we present an overview of the papers in this issue on a range of topics, including the nature of crustal and mantle heterogeneity across North America, the dynamics of the subcontinental mantle, the assembly and preservation of continental interiors, and the physics of earthquakes and faulting.

The USArray observatory (www.usarray.org) represents one of the three major infrastructure components of the National Science Foundation's EarthScope project (www.earthscope.org) and itself consists of four major elements: the seismic Reference Network, the seismic Transportable Array (TA), the magnetotelluric TA, and the Flexible Array (FA). The seismic and magnetotelluric TA efforts are designed to provide dense spatial sampling (∼70 km spacing) of geophysical data in a uniform grid across the continental US in a survey mode, while the FA provides targeted data collection driven by individual investigators aimed at specific regional problems. A critical aspect of the USArray initiative is the philosophy of open data, with USArray data made immediately available to anyone who wishes to use it (or after a short embargo in the case of FA experiments). The implementation of USArray (Fig. 1), with an emphasis on the collection and immediate dissemination of a dense, uniform, high-quality geophysical dataset to researchers worldwide, has provided an unprecedented opportunity for researchers across the Earth science disciplines.

This is a particularly exciting time for the USArray initiative. The seismic TA has been deployed by "rolling" across the continental US (and parts of eastern Canada) from west to east, with each station location occupied for approximately two years. The first TA stations were installed in 2006; in September 2013, the last TA stations were installed in the northeastern US, and coverage of the lower 48 states is now complete (Fig. 1). The USArray data have enabled a burst of research on the structure and dynamics of the North American continent and other EarthScope science targets and facilitated the development of exciting new analysis methods. The magnetotelluric (MT) component of the TA has now covered two major science targets (the Pacific Northwest and the Mid-Continent Rift; Fig. 1) and has led to some of the first three-dimensional conductivity models of the crust and mantle lithosphere. A number of Flexible Array experiments, proposed and executed by individual investigators, have been completed and are yielding insights into specific regional targets within the USArray footprint. With the ongoing expansion of USArray data availability and the recent achievement of full coverage of the lower 48 states with the seismic TA, a collection of papers on the science facilitated by the USArray observatory is timely and exciting. This special issue gathers together 32 papers that use USArray data to address a large range of topics related to the EarthScope science goals.

A particularly exciting scientific target of USArray has been the scale, amplitude, and nature of seismic wavespeed heterogeneity in the crust and mantle beneath the North American continent. A number of seismic tomography models of the upper mantle beneath the US were available in the literature before the advent of USArray, but the addition of USArray data to tomographic wavespeed inversions and investigations of body-wave travel times

* Corresponding author.
E-mail address: maureen.long@yale.edu (M.D. Long).

http://dx.doi.org/10.1016/j.epsl.2014.06.016

Please cite this article in press as: Long, M.D., et al. An introduction to the special issue of Earth and Planetary Science Letters on USArray science. Earth Planet. Sci. Lett. (2014), http://dx.doi.org/10.1016/j.epsl.2014.06.016

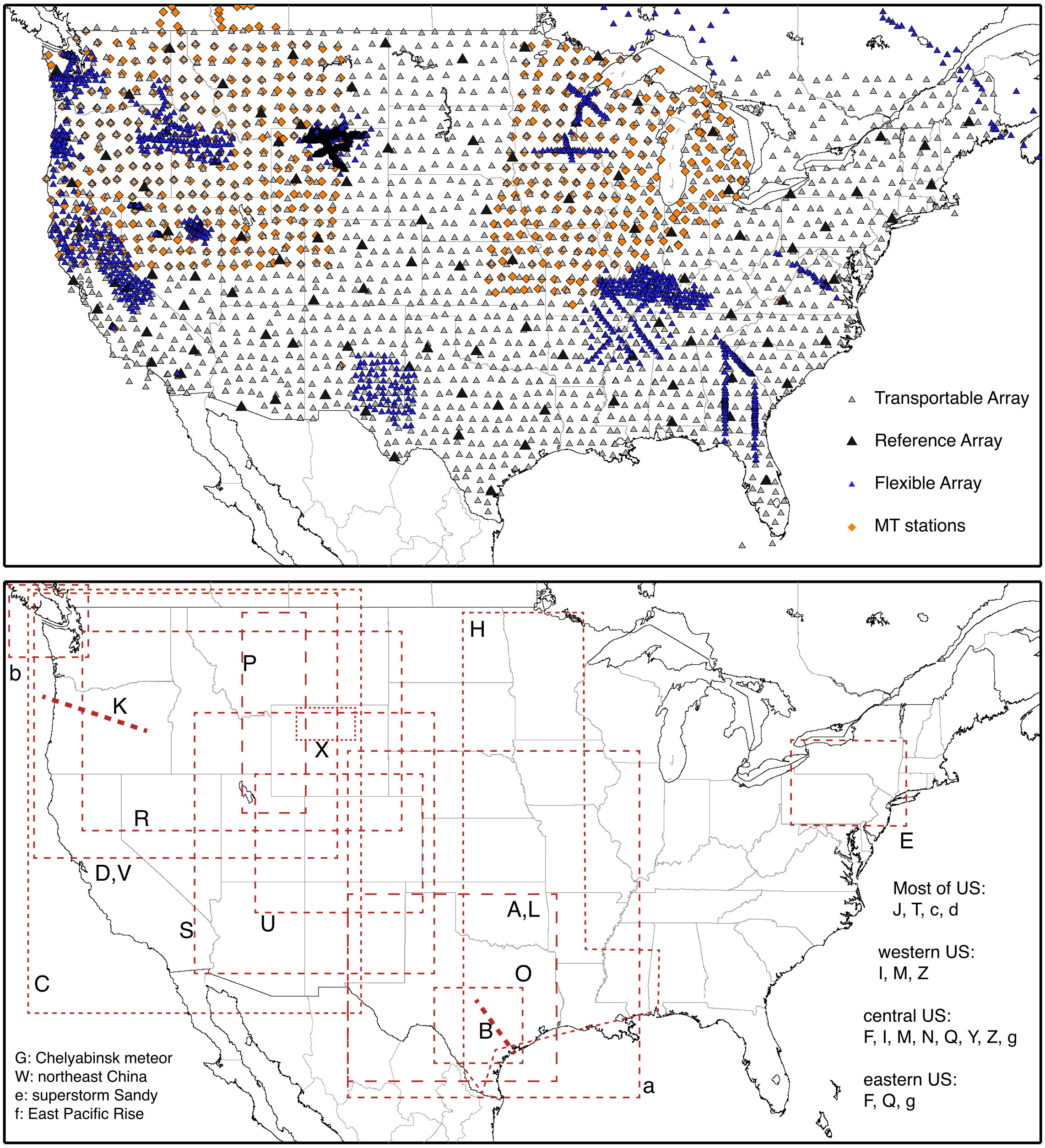

Fig. 1. (top) Map of seismic and magnetotelluric USArray stations, including the seismic Reference Network (large black triangles), the seismic Transportable Array (gray triangles), and magnetotelluric stations (orange diamonds). Small blue triangles indicate locations of Flexible Array experiments that have been executed by individual investigators. Map courtesy of Sarah Robinson/EarthScope National Office. (bottom) Approximate guide to regions studied by papers in this issue. A: Sosa et al., B: Ainsworth et al., C: Becker et al., D: Bedrosian and Feucht, E: Benoit et al., F: Chu et al., G: De Groot-Hedlin and Hedlin, H: De Groot-Hedlin et al., I: Eddy and Ekström, J: Ekström, K: Evans et al., L: Evanzia et al., M: A. Foster et al., N: K. Foster et al., O: Frohlich and Brunt, P: Gao and Liu, Q: Gallegos et al., R: Hopper et al., S: Lekić and Fischer, T: Lou and van der Lee, U: MacCarthy et al., V: Meqbel et al., W: Niu, X: O'Rourke et al., Y: Pollitz and Mooney, Z: Porritt et al., a: Refayee et al., b: Royer and Bostock, c: Schaeffer and Lebedev, d: Schulte-Pelkum and Mahan, e: Sufri et al., f: Wang et al., g: Yuan et al.

has provided a dramatic improvement in our ability to resolve structure on short length scales. In turn, the higher resolution tomography models enabled by USArray data have provoked new questions on the origin and length scales of wavespeed heterogeneity; in particular, detailed and quantitative comparisons between crust and upper-mantle wavespeeds of the tectonically active western US and the tectonically quiet continental interior are now feasible. In this issue, Lou and van der Lee (2014) use measurements of P and S teleseismic travel times to investigate the nature of upper-mantle heterogeneity beneath the USArray footprint, while Porritt et al. (2014) present an updated P and S tomographic model based on body- and surface-wave observations, with a focus on interpreting newly resolved structures east of the Rocky Mountain Front. New tomographic models of upper-mantle structure are also described by Schaeffer and Lebedev (2014), who use an automated multimode waveform approach to constrain shear wavespeed structure as deep as the mantle transition zone. A series of papers seeks to exploit the information contained in the dense USArray sampling of surface-wave propagation; Ekström (2014) presents phase-velocity maps for Love and Rayleigh wave propagation, while Eddy and Ekström (2014) and A. Foster et al. (2014) use array observations of surface-wave amplitudes and arrival angles, respectively, to constrain structure. For all of these investigations of wavespeed heterogeneity at depth, a key question is to what extent velocity structures in the crust and upper-mantle correlate with geologic and tectonic features at the surface;

Please cite this article in press as: Long, M.D., et al. An introduction to the special issue of Earth and Planetary Science Letters on USArray science. Earth Planet. Sci. Lett. (2014), http://dx.doi.org/10.1016/j.epsl.2014.06.016

detailed comparisons between surface and deep structures are enabled by the dense sampling and high spatial resolution afforded by the USArray dataset.

The origin, structure, evolution, and long-term stability of continental lithosphere represents a major unresolved challenge in Earth science, and the geophysical observations enabled by USArray are shedding light on this important problem. Several papers in this issue address the structure of the lithosphere and the lithosphere–asthenosphere boundary beneath North America. Hopper et al. (2014) use S-to-P receiver function analysis to probe the three-dimensional discontinuity structure beneath the northwestern US and find regional variations in the presence, depth, and strength of the inferred lithosphere–asthenosphere boundary (LAB) that correspond to regional tectonics. K. Foster et al. (2014) apply a similar technique to data beneath the midwestern US; interpreted in concert with surface-wave tomographic images of the same region, their analysis suggests the presence of a generally sharp LAB and an intermittent mid-lithospheric discontinuity (MLD) beneath the region. A third investigation of the discontinuity structure of the lithosphere by Lekić and Fischer (2014) finds evidence for lateral variability in the MLD and LAB depths that reflect the different tectonic and magmatic histories of regions within the western US. A paper by Gao and Liu (2014) uses a similar philosophy – investigating seismic discontinuities at depth by analyzing converted waves – but they develop a novel procedure for analyzing P-to-S conversions and apply it to study the nature of the transition-zone discontinuities (at ∼410 and ∼660 km depth) beneath the Yellowstone hotspot. They argue that no localized thinning of the transition zone is present beneath Yellowstone, as might be expected for an upwelling mantle plume.

A key component of the USArray infrastructure is a pool of seismic stations (the FA) that is available to individual investigators as they propose and carry out experiments that target specific regions or problems. This special issue contains several papers that use data from FA (or FA-style) experiments, often in combination with data from the TA and other stations, to investigate regions such as the Rocky Mountains, the Bighorn Arch, the Rio Grande Rift, and the Gulf Coast of Texas. MacCarthy et al. (2014) investigate the P and S velocity structure of the upper mantle beneath the Rocky Mountains, finding evidence from the nature of wavespeed heterogeneity for dynamic support of topography from mantle buoyancy. O'Rourke et al. (2014) use data from an array of geophones deployed as part of an FA experiment in the Bighorn Mountain Range of Wyoming to examine the geometry of sedimentary basins; a novel aspect of this study is the application of instrumentation that is usually used for active-source experiments to record distant, naturally occurring earthquake sources. A study by Sosa et al. (2014) combines data from the TA and a temporary deployment across the Rio Grande Rift to study the shear-wave velocity structure at the southern end of the rift, concluding that there is little evidence for deep mantle upwelling driving the rifting. Two papers use data from an array deployed across the coastal plain of the Texas Gulf Coast to study the structure of the passive continental margin. Ainsworth et al. (2014) use S-to-P receiver function imaging to investigate the signature of past rifting processes in the lithospheric mantle, while Evanzia et al. (2014) combine data from temporary experiments and the TA to carry out P and S velocity tomography of the upper mantle beneath the Texas and Oklahoma region.

USArray reached a major milestone in 2013 with the completion of the seismic TA in the lower 48 states. The recent coverage of the central and eastern US (CEUS) with USArray data has led to a renewed focus on this region, and this issue presents several papers that investigate CEUS structure, dynamics, and processes. Pollitz and Mooney (2014) apply a surface-wave imaging technique to produce Rayleigh-wave phase-velocity maps for the central US and find evidence for a pronounced low-velocity zone in the upper mantle beneath the Reelfoot Rift, which may play a role in concentrating stress in the vicinity of the New Madrid Seismic Zone (NMSZ). Using high-resolution waveform modeling of records from the August 2011 Mineral, VA earthquake, Chu et al. (2014) also find evidence for low seismic velocities in the lower lithosphere beneath the NMSZ, and further delineate a corridor of low velocities that extends from the NMSZ to Virginia. The structure of the lithosphere beneath the CEUS is also investigated by Yuan et al. (2014), who present a tomographic shear-velocity model that exhibits a strong correlation between upper-mantle structure and geologic and tectonic units at the surface. Gallegos et al. (2014) use TA recordings of Lg phases to probe the attenuation structure of the crust beneath the CEUS and identify correlations between regions of high crustal attenuation and those associated with high heat flow, large sediment thickness, and recent tectonic activity. Finally, Benoit et al. (2014) combine receiver-function imaging of crustal structure with gravity analysis beneath the eastern US to suggest an explanation for the bend in the Central Appalachian Mountains. They propose that strong, thickened, and underplated crust beneath a failed Proterozoic rift zone localized strain during the Appalachian orogeny, leading to the curvature of the Pennsylvania Salient.

Along with characterizing deep structure of the North American continent, understanding crustal and mantle dynamics and the physics of earthquakes and faulting also represent major scientific targets for the USArray initiative. Refayee et al. (2014) present a large dataset of shear-wave splitting measurements from the southwestern US, which reflect mantle deformation. They conclude that partial coupling between the lithosphere and underlying asthenosphere is likely, and that the North American cratonic root plays a role in deflecting mantle flow. Schulte-Pelkum and Mahan (2014) propose a novel technique for characterizing crustal anisotropy based on P-to-S converted waves and apply it to TA data, documenting lateral variations in the strength and orientation of crustal anisotropy across the continent. Becker et al. (2014) investigate the dynamics of the subcontinental mantle by modeling topographic variations beneath the western US, taking advantage of improved models of crustal structure from USArray data. They find that the non-isostatic, or dynamic, component of topography is large, and that mantle flow models match many of its first-order features. A paper by Royer and Bostock (2014) addresses the physics of low-frequency earthquakes (LFEs) in Cascadia by analyzing waveforms recorded at TA, FA, and other stations, including data from the Plate Boundary Observatory (PBO) component of EarthScope. Their analysis reveals that Cascadia LFEs generally exhibit moment tensors that are consistent with shallow thrusting along the plate motion direction. Finally, Frohlich and Brunt (2014) use data from the deployment of the TA in Texas to investigate patterns of small-magnitude seismicity in and around the Eagle Ford Shale, which is currently producing natural gas. They identify possible spatial correlations between earthquake locations and the locations of injection and production wells, and hypothesize that there may have been a causal relationship between oil and water extraction and the magnitude 4.8 Fashing earthquake in October 2011.

The collection of the USArray dataset has led to a drastic expansion in the availability of electromagnetic observations in continental North America, providing constraints on lithospheric structure and composition that are complementary to those provided by seismology. As with the seismic component, USArray MT data are being collected both in survey mode (the MT TA) and as targeted regional investigations. Evans et al. (2014) take advantage of both types of data, combining MT TA observations with a legacy data set (the EMSLAB experiment) and applying improved analysis methods to obtain a new conductivity model for a transect across

Please cite this article in press as: Long, M.D., et al. An introduction to the special issue of Earth and Planetary Science Letters on USArray science. Earth Planet. Sci. Lett. (2014), http://dx.doi.org/10.1016/j.epsl.2014.06.016

the Cascadia subduction zone. A notable feature of their model is a high-conductivity feature in the forearc that is consistent with the release of fluids into the overlying crust from dehydration reactions in the slab. Two complementary papers in the special issue (Bedrosian and Feucht, 2014; Meqbel et al., 2014) present conductivity models of the crust and upper mantle for the northwestern US, taking advantage of the first completed footprint of the MT TA (Fig. 1). These studies are among the first to produce well-resolved regional three-dimensional conductivity models, and the new images of conductivity structure beneath the northwestern US provide fertile ground for comparison with seismic velocity models obtained at similar scales, as well as geologic and tectonic features at the surface.

While the main scientific focus of EarthScope is the structure of the North American continent, the design of USArray lends itself to other types of studies as well, including investigations that are geared towards the imaging of distant structures and studies of non-earthquake sources such as storms and meteor impacts. In this issue, Niu (2014) applies array analysis to USArray records from deep earthquakes beneath China and finds evidence for S-to-P reflections from low-velocity, high-density structures in the lower mantle, which may correspond to subducted oceanic crust. Wang et al. (2014) model S and SS waveforms from earthquakes along the East Pacific Rise recorded at USArray (and other) stations to probe the structure of the mantle transition zone; they conclude that the 410 and 660 km discontinuities are associated with large velocity jumps that are consistent with a pyrolite mantle composition. In the realm of characterizing non-earthquake sources, Sufri et al. (2014) present an analysis of the microseism generated by Superstorm Sandy as it approached the US east coast, derived from frequency-dependent polarization analysis at TA stations. De Groot-Hedlin and Hedlin (2014) use data from the microbarometers co-located at TA seismic stations to characterize infrasound propagation through the atmosphere following the Chelyabinsk, Russia meteor event in February 2013. Finally, De Groot-Hedlin et al. (2014) develop a method for processing array barometric data from the TA to detect long-period atmospheric wave phenomena and detect gravity waves, or gust fronts, associated with a storm system in the southern US in late April 2011.

This is an exciting time for the community of USArray researchers and for the EarthScope initiative, and the research presented in this special issue represents only a sampling of the discoveries being unearthed by the USArray. The ten-year anniversary of EarthScope has recently passed, with five more years of data collection and science investigations to come. With the arrival of the seismic TA on the east coast of the US, a major technical goal of EarthScope – the collection of a uniform and dense geophysical dataset across continental North America – has been achieved. As the papers in this special issue demonstrate, USArray has enabled cutting-edge investigations into the structure and evolution of the North American continent while facilitating novel analyses, methods, investigations, and discoveries that were often unanticipated when the facility was being planned. The focus of USArray data collection will soon shift towards Alaska, even as the data collected thus far will continue to facilitate new discoveries for years to come. The ongoing integration of the geophysical constraints derived from USArray data with constraints from other disciplines (e.g., geology, geochemistry, petrology, geodynamics) represents an exciting frontier in the study of continental dynamics and evolution.

References

Ainsworth, R., Pulliam, J., Gurrola, H., Evanzia, D., 2014. Sp receiver function imaging of a passive margin: transect across Texas' Gulf Coastal Plain. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.05.056.

Becker, T.W., Faccenna, C., Humphreys, E.D., Lowry, A.R., Miller, M.S., 2014. Static and dynamic support of western United States topography. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.10.012.

Bedrosian, P.A., Feucht, D.W., 2014. Structure and tectonics of the northwestern United States from EarthScope USArray magnetotelluric data. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.07.035.

Benoit, M.H., Ebinger, C., Crampton, M., 2014. Orogenic bending around a rigid Proterozoic magmatic rift beneath the Central Appalachian Mountains. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.03.064.

Chu, R., Helmberger, D., Gurnis, M., 2014. Upper mantle surprises derived from the recent Virginia earthquake waveform data. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2012.10.023.

De Groot-Hedlin, C.D., Hedlin, M.A.H., 2014. Infrasound detection of the Chelyabinsk meteor at the USArray. Earth Planet. Sci. Lett. http://dx.doi.org/10.1026/j.epsl.2014.01.031.

De Groot-Hedlin, C.D., Hedlin, M.A.H., Walker, K.T., 2014. Detection of gravity waves across the USArray: a case study. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.06.042.

Eddy, C.L., Ekström, G., 2014. Local amplification of Rayleigh waves in the continental United States observed on the USArray. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.01.013.

Ekström, G., 2014. Love and Rayleigh phase-velocity maps, 5–40 s, of the western and central USA from USArray data. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.11.022.

Evans, R.L., Wannamaker, P.E., McGary, R.S., Elsenbeck, J., 2014. Electrical structure of the central Cascadia subduction zone: the EMSLAB Lincoln Line revisited. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.04.021.

Evanzia, D., Pulliam, J., Ainsworth, R., Gurrola, H., Pratt, K., 2014. Seismic Vp & Vs tomography of Texas & Oklahoma with a focus on the Gulf Coast margin. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.12.027.

Foster, A., Ekström, G., Hjörleifsdóttir, V., 2014. Arrival-angle anomalies across the USArray Transportable Array. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.12.046.

Foster, K., Dueker, K., Schmandt, B., Yuan, H., 2014. A sharp cratonic lithosphere–asthenosphere boundary beneath the American Midwest and its relation to mantle flow. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.11.018.

Frohlich, C., Brunt, M., 2014. Two-year survey of earthquakes and injection/production wells in the Eagle Ford Shale, Texas, prior to the 20 October 2011 earthquake. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.07.025.

Gallegos, A., Ranasinghe, N., Ni, J., Sandvol, E., 2014. Lg attenuation in the central and eastern United States as revealed by the EarthScope Transportable Array. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.01.049.

Gao, S.S., Liu, K.H., 2014. Imaging mantle discontinuities using multiply-reflected P-to-S conversions. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl/.2013.08.025.

Hopper, E., Ford, H.A., Fischer, K.M., Lekic, V., Fouch, M.J., 2014. The lithosphere–asthenosphere boundary and the tectonic and magmatic history of the northwestern United States. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.12.016.

Lekić, V., Fischer, K.M., 2014. Contrasting lithospheric signatures across the western United States revealed by Sp receiver functions. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.11.026.

Lou, X., van der Lee, S., 2014. Observed and predicted North American teleseismic delay times. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.11.056.

MacCarthy, J.K., Aster, R.C., Dueker, K.G., Hansen, S.M., Schmandt, B., Karlstrom, K.E., 2014. Seismic tomography of the Colorado Rocky Mountains upper mantle from CREST: lithosphere–asthenosphere interactions and mantle support of topography. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.03.063.

Meqbel, N.M., Egbert, G.D., Wannamaker, P.E., Kelbert, A., Schultz, A., 2014. Deep electrical resistivity structure of the northwestern U.S. derived from 3-D inversion of USArray magnetotelluric data. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.12.026.

Niu, F., 2014. Distinct compositional thin layers at mid-mantle depths beneath northeast China revealed by the USArray. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.02.015.

O'Rourke, C.T., Sheehan, A.F., Erslev, E.A., Miller, K.C., 2014. Estimating basin thickness using a high-density passive-source geophone array. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.10.035.

Pollitz, F.F., Mooney, W.D., 2014. Seismic structure of the Central US crust and shallow upper mantle: uniqueness of the Reelfoot Rift. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.05.042.

Porritt, R.W., Allen, R.M., Pollitz, F.F., 2014. Seismic imaging east of the Rocky Mountains with USArray. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.10.034.

Refayee, H.A., Yang, B.B., Liu, K.H., Gao, S.S., 2014. Mantle flow and lithosphere–asthenosphere coupling beneath the southwestern edge of the North American craton: constraints from shear-wave splitting measurements. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.01.031.

Royer, A.A., Bostock, M.G., 2014. A comparative study of low frequency earthquake templates in northern Cascadia. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.08.040.

Schaeffer, A., Lebedev, S., 2014. Imaging the North American continent using waveform inversion of global and USArray data. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.05.014.

Schulte-Pelkum, V., Mahan, K.H., 2014. A method for mapping crustal deformation and anisotropy with receiver functions and first results from USArray. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.01.050.

Sosa, A., Thompson, L., Velasco, A.A., Romero, R., Herrmann, R.B., 2014. 3-D structure of the Rio Grande Rift from 1-D constrained joint inversion of receiver functions and surface wave dispersion. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2014.06.002.

Sufri, O., Koper, K.D., Burlacu, R., de Foy, B., 2014. Microseismics from Superstorm Sandy. Earth Planet. Sci. Lett. http://dx.doi.org/10.0116/j.epsl.2013.10.015.

Wang, Y., Grand, S.P., Tang, Y., 2014. Shear velocity structure and mineralogy of the transition zone beneath the East Pacific Rise. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.07.038.

Yuan, H., French, S., Cupillard, P., Romanowicz, B., 2014. Lithospheric expression of geological units in central and eastern North America from full waveform tomography. Earth Planet. Sci. Lett. http://dx.doi.org/10.1016/j.epsl.2013.11.057.