

This Agreement is between the author (Author) and ProQuest LLC, through its UMI® Dissertation Publishing business (ProQuest/UMI). Under this Agreement, Author grants ProQuest/UMI certain rights to preserve, archive and publish the dissertation or thesis, abstract, and index terms (the Work) provided by Author to ProQuest/UMI.

## Section I. License for Inclusion of the Work in UMI® Publishing Program.

**Grant of Rights.** Author hereby grants to ProQuest/UMI the **non-exclusive**, worldwide right to reproduce, distribute, display and transmit the Work (in whole or in part) in such tangible and electronic formats as may be in existence now or developed in the future. Author further grants to ProQuest/UMI the right to include the abstract, bibliography and other metadata in the ProQuest Dissertations & Theses database (PQDT) and in ProQuest/UMI's Dissertation Abstracts International and any successor or related index and/or finding products or services.

**UMI® Publishing Program - Election and Elements.** The rights granted above shall be exercised according to the publishing option selected by Author in Section III, Author Options, and subject to the following additional Publishing Program requirements:

- **Redistribution of the Work.** Except as restricted by Author in the publishing option selected, the rights granted by Author automatically include (1) the right to allow sale and distribution of the Work, in whole or in part, by agents and distributors, including but not limited to commercial retail outlets and (2) the right to make the Abstract, bibliographic data and any meta data associated with the Work available to search engines and harvesters.
- **Restrictions.** ProQuest/UMI will use commercially reasonable efforts to restrict the distribution of the Work as provided under the publishing option selected by Author or as later elected by Author through direct contact with ProQuest/UMI. Such election is subject to Author's Degree Granting Institution Directives (see below). With respect to restrictions requested after submission of the Work, Author acknowledges that ProQuest/UMI cannot recall or amend previously distributed versions of the Work.
- **Removal of Work from the Program.** ProQuest/UMI may elect not to distribute the Work if it believes that all necessary rights of third parties have not been secured. Refer to the website [http://www.proquest.com/products\\_umi/dissertations/](http://www.proquest.com/products_umi/dissertations/) for information about copyright and your dissertation or thesis. If Author's degree is rescinded, and the degree-granting institution so directs, ProQuest/UMI will expunge the Work from its publishing program in accordance with its then current publishing policies.
- **Degree Granting Institution Directives.** Author is solely responsible for any conflict between policies and directions of Author's degree-granting institution, Author's choice of publishing model, and/or any restriction Author places on the use of the Work. For the avoidance of doubt, ProQuest/UMI is not responsible for access to the Work that is provided by Author's degree-granting institution through its library or institutional repository. Author must work directly with Author's degree granting institution to ensure application of

any restrictions to access relating to the Work by Author's degree granting institution.

**Copyright and Deposit with the Library of Congress.** At Author's option and upon payment of the applicable fee, ProQuest/UMI will submit an application for registration of **Author's copyright** in the Work in Author's name. In addition, regardless of whether copyright registration of the Work is sought, ProQuest/UMI may make a copy of the Work available to the Library of Congress in digital, microform or other format as required by the Library of Congress.

**Publishing Fees and Royalties.** Author shall remit the publishing fees and the optional copyright registration fees as appropriate for the publishing option chosen by Author, and as specified by Author's degree-granting institution. Except as provided under the Traditional Publishing option, no royalties shall be due from ProQuest/UMI to Author.

**Delivery of the Work.** Author shall provide to ProQuest/UMI the Work and all necessary supporting documents during the online submission process, according to the Instructions accompanying this agreement.

**Rights Verification.** Author represents and warrants that Author is the copyright holder of the Work and has obtained all necessary rights to permit ProQuest/UMI to reproduce and distribute third party materials contained in any part of the Work, including all necessary licenses for any non-public, third party software necessary to access, display, and run or print the Work. Author is solely responsible and will indemnify ProQuest/UMI for any third party claims related to the Work as submitted for publication.

## Section II-A. Rights pursuant to Traditional Publishing.

Author's election of Traditional as the Type of Publishing confirms Author's choice to have ProQuest/UMI publish the Work according to the Traditional Publishing option described below.

**Traditional Publishing.** ProQuest/UMI may exercise the rights granted under Section I above including through the sale of individual copies of the Work in tangible or electronic media and/or as part of electronic database and reference products or services.

**Publishing Fees and Royalties.** Author's payment of the dissertation or thesis publishing fee is a one-time, up-front fee. Author's institution may assess additional fees to be collected along with the publishing fee. ProQuest/UMI will pay royalties of 10% of its net revenue from sales of the Work, conditioned on Author maintaining a current address on record with ProQuest/UMI. Royalties will be paid when accrued earned royalties reach \$25.00. If, after 25 years, earned royalties do not accrue to at least \$25.00, ProQuest/UMI's royalty payment obligation will cease.

## Section II-B. Rights pursuant to Open Access Publishing PLUS.

Author's election of Open Access Publishing PLUS as the Type of Publishing confirms Author's choice to have ProQuest/UMI publish the Work according to the Open Access Publishing PLUS option described here.

Open Access Publishing PLUS. In addition to the rights granted under Section I of this UMI® Publishing Agreement, ProQuest/UMI may reproduce, distribute, display and transmit the Work in electronic format in the ProQuest Dissertations & Theses database, where it may be made available for free download. A subset of the ProQuest Dissertations & Theses database, currently known as PQDT Open, may be accessed by the academic community as well as through major search engines and open access harvesters. ProQuest/UMI may also provide an electronic copy of the Work to Author's degree-

granting institution where it may also be posted for free open access. Learn more: <http://www.proquest.com/en-US/products/dissertations/epoa.shtml>

Copy Sales. ProQuest/UMI and its agents and distributors may offer copies of the Work for sale in tangible media, including but not limited to microform, print and CD-ROM, as well as in electronic format either individually or as part of its electronic database and reference products and services. No royalties shall be due to Author.

Publishing Fees. Author's payment of the additional Open Access Publishing PLUS fee is a one-time, up-front fee in addition to the UMI® dissertation or thesis publishing fee. Author's institution may assess additional fees to be collected along with the Open Access and publishing fee.

### Section III. Publishing Options & Signature

Select the publishing options below that best fit your interests and scholarly publishing obligations.

#### Traditional Publishing

- I want to make my work widely available and I want to be eligible to receive royalties on the sale of my work.
- I understand that I must maintain a current mailing address with ProQuest/UMI in order to be eligible to receive royalties.
  - I understand that the ProQuest/UMI fee for Traditional Publishing is \$25 for Master's thesis and \$25 for Doctoral dissertations.
  - I understand that my graduate institution may pay all or a portion of the total fee as well as may require additional fees in association with my submission to ProQuest/UMI.

#### Open Access Publishing PLUS

- I want the broadest possible dissemination of my work, and I want to provide free global access to the electronic copy of my work via the internet.
- I understand that I will not be eligible to receive royalties.
  - I understand that the ProQuest/UMI fee for Open Access Publishing PLUS of Master's thesis is \$120 and for Dissertations is \$120, and that my graduate institution may pay all or a portion of the total fee as well as may require additional fees in association with my submission to ProQuest/UMI.

#### SELECT PUBLISHING OPTIONS

##### I want my work to be available as soon as it is published

- Yes
- No – I would like access to the full text of my work to be delayed for the following period of time:
- 6 month embargo
  - 1 year embargo
  - 2 year embargo

Note: Most institutions have delayed release (embargo) policies, please consult with your Graduate School/Program, if you need to delay the release of your work. Access to the full-text of your work will be delayed for the time period specified above, beginning from the date that we receive your manuscript at ProQuest/UMI. During this time, only your citation and abstract will appear in the ProQuest Dissertations & Theses Database (PQDT).

I want major search engines (e.g. Google, etc...) to discover my work. Learn more: <http://www.proquest.com/en-US/products/dissertations/google.shtml>

- Yes
- No

I want my graduate work to be sold by third party retailers in addition to ProQuest/UMI. (Note: If Traditional Publishing is chosen above, all sales are eligible to accrue royalties.)

- Yes
- No

Acknowledgment: I have read, understand and agree to this UMI® Publishing Agreement, including all rights and restrictions included within the publishing option chosen by me as indicated above.

REQUIRED Author's signature Kathy Davenport Date 9/18/2016  
(Print Name) Kathy Davenport  
Institution conferring degree Virginia Polytechnic Institute and State University

Questions: Our Author Relations Team is available by phone at (800) 521-0600 ext.7020 or by email at [disspub@proquest.com](mailto:disspub@proquest.com)  
Need help selecting a subject heading? Contact our editors at (800)-521-0600 ext. 4883 (Social Sciences/Humanities) or ext. 2209(Sciences/Engineering)

**Dissertation/Master's Thesis Submission Form**

Please print clearly in block letters

 M (Master's Thesis) D (Dissertation)**Personal Information**

Last Name Davenport Middle Name or Initial K  
 First Name Kathy Country (ies) of Citizenship U.S.

**Degree & Dissertation Information**

Title of Dissertation/ Thesis Continental Tectonics from Dense Array Seismic Imaging: Intraplate Seismicity in Virginia and a Steep Cratonic Margin in Idaho  
 Institution conferring degree Virginia Polytechnic Institute and State University Degree awarded (abbreviate; e.g., Ph.D.) Ph.D.  
 College, School, or Division College of Science Year degree awarded 2016  
 Department or Program Department of Geosciences Year manuscript completed 2016  
 Advisor/Committee Chair John A. Hole  
 Committee Member Ying Zhou Committee Member James A. Spotila  
 Committee Member Basil Tikoff Committee Member \_\_\_\_\_  
 Committee Member Martin C. Chapman Committee Member \_\_\_\_\_

Language of manuscript English  
 Primary Subject Category: Enter the 4-digit code and category name from Guide 2 that most closely describes the disciplinary area of your research.

Code 0373 Category Geophysics

You may suggest two additional subject categories that may aid in the discovery of your work in our digital database.

Code 0372 Category Geology Code 0592 Category Plate Tectonics

Provide up to 6 keywords or short phrases for citation indices, library cataloging, and database searching.

Dense Arrays Western Idaho shear zone Virginia earthquake  
Travel time tomography Moho offset Controlled-source seismic

**Current Contact Information**Current Email Address davenport.k42@gmail.comStreet Address (line 1) 1746 Rose Street

Street Address (line 2) \_\_\_\_\_

City Junction City State/Province OR Daytime Phone 423-612-3212Country USA Postal Code 97448 Evening Phone \_\_\_\_\_**Permanent Contact Information**Permanent Email Address davenport.k42@gmail.comStreet Address (line 1) 112 Fisher Dr.

Street Address (line 2) \_\_\_\_\_

City Kingsport State/Province TN Future Phone 423-612-3212Country USA Postal/ZIP code 37664 Alternate Future Phone \_\_\_\_\_

**THIS PAGE MUST ACCOMPANY YOUR MANUSCRIPT AND THE REST OF YOUR SUBMISSION MATERIALS**  
*Attach additional, separate copies of your Title Page and Abstract to this form*

**Continental Tectonics from Dense Array Seismic Imaging: Intraplate Seismicity in  
Virginia and a Steep Cratonic Margin in Idaho**

Kathy K. Davenport

Dissertation submitted to the faculty of the Virginia Polytechnic Institute and State University in  
partial fulfillment of the requirements for the degree of

Doctor of Philosophy

In

Geosciences

John A. Hole

Martin C. Chapman

Ying Zhou

James A. Spotila

Basil Tikoff

September 7, 2016

Blacksburg, VA

**Keywords:** Dense arrays, Travel time tomography, Western Idaho shear zone, Moho offset,  
Virginia earthquake, Controlled-source seismic

Chapter 2 © 2014 by The Geological Society of America

All other material © 2016 by Kathy Davenport

# **Continental Tectonics from Dense Array Seismic Imaging: Intraplate Seismicity in Virginia and a Steep Cratonic Margin in Idaho**

Kathy K. Davenport

## **ABSTRACT**

Dense array seismic techniques can be applied to multiple types of seismic data to understand regional tectonic processes via analysis of crustal velocity structure, imaging reflection surfaces, and calculating high-resolution hypocenter locations. The two regions presented here include an intraplate seismogenic fault zone in Virginia and a steep cratonic margin in eastern Oregon and Idaho.

The intraplate seismicity study in Virginia consisted of using 201 short-period vertical-component seismographs, which recorded events as low as magnitude -2 during a period of 12 days. Dense array analysis revealed almost no variation in the seismic velocity within the hypocentral zone, indicating that the aftershock zone is confined to a single crystalline-rock terrane. The 1-2 km wide cloud of hypocenters is characterized by a 29° strike and 53° dip consistent with the focal mechanism of the main shock. A 5° bend along strike and a shallower dip angle below 6 km points toward a more complex concave shaped fault zone.

The seismic study in Idaho and Oregon was centered on the inversion of controlled-source wide-angle reflection and refraction seismic P- and S-wave traveltimes to determine a seismic velocity model of the crust beneath this part of the U.S. Cordillera. We imaged a narrow, steep velocity boundary within the crust that juxtaposes the Blue Mountains accreted terranes and the North American craton at the western Idaho shear zone. We found a 7 km offset in Moho depth, separating crust with different seismic velocities and Poisson's ratios. The crust beneath the Blue Mountains terranes is consistent with an intermediate lithology dominated by diorite. In the lower crust there is evidence of magmatic underplating which is consistent with the location of the feeder system of the Columbia River Basalts. The cratonic crust east of the WISZ is thicker and characterized by a felsic composition dominated by granite through most of the crust, with an intermediate composition layer in the lower crust. This sharp lithologic and rheologic boundary strongly influenced subsequent deformation and magmatic events in the region.