Seismic Waveform Tomography across the Seattle Fault Zone in Puget Sound: Resolution Analysis and Effectiveness of Visco-acoustic Inversion of Visco-elastic Data

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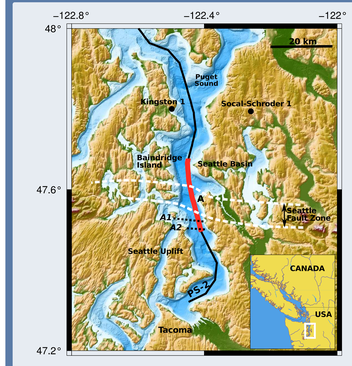
Objectives

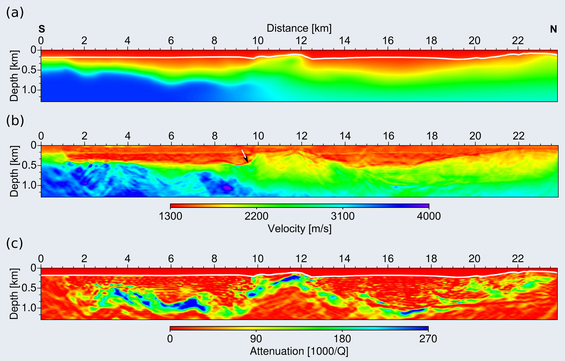
1. Application of visco-acoustic waveform tomography (Pratt, 1999) to seismic reflection data across the Seattle Fault Zone (SFZ) in Puget Sound to obtain high resolution velocity and attenuation images.
2. Verify the effectiveness of applying acoustic waveform tomography to visco-elastic field data using visco-elastic synthetic checkerboard tests.
3. A Magnitude 7 earthquake occurred on the SFZ about 1,100 years ago, and the SFZ is considered a major seismic hazard.Structural interpretations of the seismogenic faults based on seismic surveys are ambiguous due to the absence of clear reflections from fault planes, or from stratigraphy within the fault zone leading to contradicting interpretations of the SFZ.
4. Utilize the higher resolution velocity and attenuation models available from waveform tomography to identify structures not visible in conventional seismic images and to refine the interpretation of this complex area.

Study Area and Seismic Survey



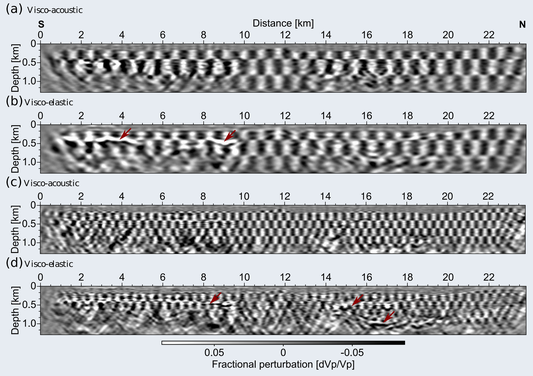
Map of the Puget Lowland with line PS-2 from the SHIPS seismic survey. The section highlighted in red was used for this study. The locations of the Kingston 1 and Socal-Shroder 1 wells are indicated. **A** indicates Alki point; ***A1***-Blake Island anticline and ***A2***-Winghaven Park anticline.

Results: Velocity and Attenuation



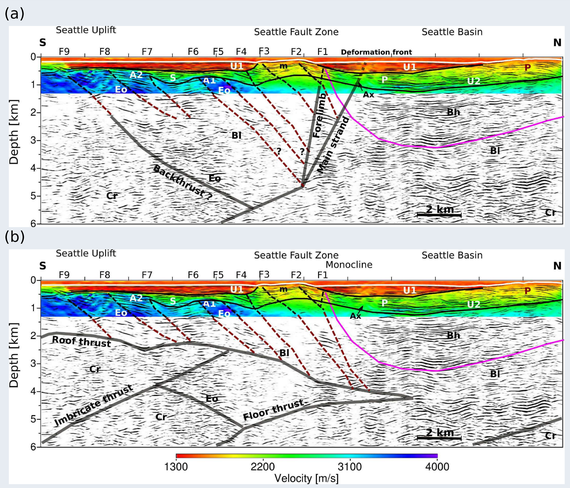
Waveform tomography results using frequencies from 4.4 Hz to 17.6 Hz: (a) starting velocity model derived from traveltime tomography, (b) final velocity model from waveform tomography and (c) associated attenuation model. The starting attenuation model is a homogeneous model with Q_p=100. The arrow indicates anomalously low velocity at layer interfaces due to mode conversions.

Resolution Test: Velocity



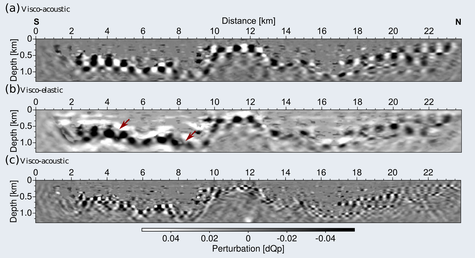
400 m and 200 m recovered velocity perturbation pattern from the acoustic ((a) and (c)) and elastic ((b) and (d)) modeled data. The perturbations are 5 % of the actual velocity model. The quality of the elastic model is comparable to the acoustic model for the 400 m perturbation size, but for the 200 m perturbation size, the quality of the model is degraded in places by artifacts due to elastic mode conversions (indicated with arrows).

Interpretation



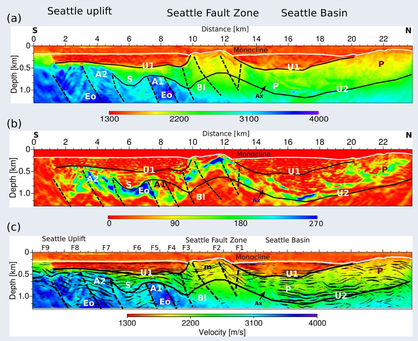
Superposition of the final velocity model on the migrated seismic reflection section truncated at 6 km depth. (a) Interpretation of SFZ as a fault probation fold with a forelimb breakthrough (Pratt et al., 1997; Liberty et al., 2008), and (b) as the leading edge of the triangle zone of a passive roof duplex (Brocher, 2004).

Resolution Test: Attenuation



400 m and 200 m recovered attenuation perturbation patterns from the visco-acoustic ((a) and (c)) and visco-elastic ((b)) modeling. The perturbations are 50 % of the actual attenuation model. The undulating high attenuation layer along the model has been well recovered in the visco-acoustic modeling. The checkerboard pattern is less well recovered with visco-elastic modeling and artifacts are present between 1 and 12 km.

Interpretation



(a) velocity model, (b) attenuation model and (c) velocity and migrated section. F1-F9 are thrust faults; Eo-Eocene volcanics; Ax-Axial surface within the monocline; P-glacial Pleistocene; U1-Pleistocene-Holocene/glacial Pleistocene unconformity; U2-Tertiary/Quaternary unconformity; A1-Blake Island anticline; A2-Winghaven Park anticline; S-syncline; Bl-Blakeley Formation; m shows seafloor multiples.

Conclusions

1. The application of visco-acoustic waveform tomography to marine visco-elastic data is valid when velocity contrasts are small. When strong velocity contrasts exist, the quality of the model is degraded by artifacts arising from elastic mode conversions at layer interfaces.
2. Joint interpretation of the derived velocity and attenuation models enables us to identify Quaternary (glacial and post-glacial Pleistocene), Tertiary sedimentary and Eocene volcanic rocks. Several shallow north dipping faults, anticlines and a syncline are identified across the Seattle uplift and the Seattle fault zone.
3. Two possible models for the SFZ: either a thrust fault that accommodates north-south shortening by forming a fault-propagation fold with a forelimb breakthrough, or part of a passive roof duplex in which the SFZ is located at the leading edge of a triangle zone that is propagating into the Seattle Basin.

References

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Acknowledgments

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