Introduction

Elastic Tensor Library Information
The following supplement includes the table captions for the elastic tensor library (Tables S1-S17). All tables are uploaded separately in a data repository as excel files. Information about how each of these tensors were calculated are explained in the text. Each tensor is listed for a given dominant slip system (as listed in Table 1), density, starting single crystal elastic tensor, strain, and deformation geometry. The shear direction is the X1 or a-axis. The normal to the shear plane is the X2 or b-axis.

The first supplemental figure shows predicted splitting patterns for a subset of the elastic tensors for horizontal shear along the core-mantle boundary for ScS, SKS, and SKKS. The next supplement figure shows additional modeling results for regions of interest (Siberia and North America) since these regions were less constrained overall.
Table S1
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% bridgmanite with the slip system (100)[010] + (100)[011] with three different single crystal elastic tensors (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

Table S2
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% bridgmanite with the slip system (001) with three different single crystal elastic tensors (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

Table S3
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% ferropericlase with the slip system {110}<1-10>.

Table S4
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% ferropericlase with the slip system {100}<011>.

Table S5
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% post-perovskite with the slip system (010)[100], Ppv 1, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

Table S6
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% post-perovskite with the slip system (001)[100], Ppv 2, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

Table S7
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 100% post-perovskite with the slip systems {011}<0-11> + (010)<100>, Ppv 3, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

Table S8
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% bridgmanite and 25% ferropericlase with the slip systems (100)[010] + (100)[011] and {110}<1-10>, respectively, with three different single crystal elastic tensors for bridgmanite (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

Table S9
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% bridgmanite and 25% ferropericlase with the slip systems (100)[010] +
(100)[011] and {100}<011>, respectively, with three different single crystal elastic tensors for bridgmanite (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

**Table S10**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% bridgmanite and 25% ferropericlase with the slip systems (001) and {110}<1-10>, respectively, with three different single crystal elastic tensors for bridgmanite (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

**Table S11**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% bridgmanite and 25% ferropericlase with the slip systems (001) and {100}<011>, respectively, with three different single crystal elastic tensors for bridgmanite (Wentzcovitch et al., 2006: 125 GPa; Wookey et al., 2005b: 126 GPa and 136 GPa).

**Table S12**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 1 and {110}<1-10>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

**Table S13**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 1 and {100}<011>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

**Table S14**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 2 and {110}<1-10>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

**Table S15**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 2 and {100}<011>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

**Table S16**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 3 and {110}<1-10>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).

**Table S17**
Library of VPSC-derived elastic tensors for various strains under simple shear, pure shear, and extension for 75% post-perovskite and 25% ferropericlase with the slip systems of Ppv 3 and \{100\}<011>, respectively, with four different single crystal elastic tensors for post-perovskite (Wentzcovitch et al., 2006: 125 GPa and 140 GPa; Stackhouse et al., 2005: 135 GPa and 136 GPa).
Figures:

Figure S1
Predicted fast-axis direction in ray reference frame for ScS (first column), SKKS (middle column), SKS (left column) for each elastic tensor, assuming horizontal shear (parallel to the core-mantle boundary) with 100% strain. Colors represent simple shear (blue), pure shear (orange), and gray (extension). (a) Represents results for 100% post-perovskite (Ppv 11) with the slip system (010)<100>. (b) Represents results for 100% Ppv 2 with the slip system (001)<100>. (c) Represents results for 100% Ppv 3, which represents the combined slip systems {011}<011> and (010)<100>. (d) Represents results for 100% bridgmanite on the higher pressure slip plane (100). (e) Represents results for the 100% ferropericlase on the higher pressure slip system {100}<011>. 
Figure S2
Pole figures for the upper hemispherical projection of the top 20% of all possible shear directions (top row) and shear plane normal (bottom row) for each dataset in (a) Siberia, (b) Wester US, (c) Central America, and (d) Caribbean that includes only ScS shear wave splitting. Colors represent a different mineral or different slip system. Only ferropericlase (Fp) and two slip systems for Ppv are shown because these models demonstrated to consistently fit results in all datasets in this study. All results represent 100% strain for simple shear scenarios. (black stars) Upper hemispherical projections of the averaged velocity vectors from the plate reconstruction model (PlateRecon) of Flament (2019). (black hexagram) Upper hemispherical projections of the averaged velocity vectors from the tomography-based model (TomoDT) of Walker et al. (2011).

(a) Siberia

(b) Western US