Supplementary Material

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Here, we discuss additional material for the lithospheric complement computation discussed in the main text. Whenever we estimate average asthenospheric anisotropy, we compute an arithmetic average of tensors and then use the Christoffel matrix approach and that mean tensor to get average SKS. To match average splitting, we align and scale a lithospheric tensor before averaging by means of a parameter space search. When accounting for back-azimuth dependence, we use a parameter space search and Silver and Savage's (1994) approach.

To illustrate that our approach of inverting for best-fit lithospheric anisotropy layer gives reliable results, we picked 11 stations throughout the study area, and show in Fig. S1 that the apparent splitting parameters from the resulting hypothetical two-layer anisotropy are similar to the station averaged splitting parameters from SWS. Moreover, the two layer model from the constrained inversion where we fix the asthenospheric (lower) layer to that expected from an average of our flow model predicted

LPO is usually similar to that of a station measurement only based two layer model.

We do not expect the resulting lithospheric complement to be exactly the same as the top layer from SWS two-layer inversion. However, when the flow predicted anisotropy has similar orientation with the bottom layer from the two-layer inversion of SWS, the hypothetical lithospheric anisotropy is also similar to the top layer of the SWS two-layer inversion (Fig. S1), suggesting the validity of this approach.

Figs. S2a and b show a comparison between the SWS top layer anisotropy and our hypothetical lithospheric complement. The SWS top layer anisotropy has a wider range of azimuthal orientations and delay times (Fig. S2a), while the hypothetical lithospheric complement shows more smooth and regionally consistent anisotropy patterns, and less variation in delay times. Although differences exist, we see consistency between the two top layer anisotropy estimations in the central U.S. where there is relatively small delay time, in the Great Basin where there is the near circular anisotropy pattern, in the southern Basin and Range where there is the NE-SW anisotropy pattern, and in the eastern U.S. where there is the Appalachian Mountain parallel anisotropy pattern.

We also explore a simple method of matching the SWS observation by inverting for the best-fit thickness and anisotropy orientation of a lithospheric layer that consists of frozen-in anisotropy represented by a single elastic tensor. The tensor used here is an averaged single-crystal tensor with 70% olivine and 30% pyroxene from Estey and Douglas (1986). Instead of using a two layer fit and accounting for back-azimuth dependence of splits, we then only seek to match the average fast axes by means of a simple averaging approach. Using this simple method, the resulting hypothetical lithospheric anisotropy show similar orientations to our two layer inversion approach, but the delay time is overall larger (Fig. S2b and c). With the result from this, we can try fit the two-layer anisotropy from this simple method for $\pi/2$ backazimuth distribution, and compare it to the fit from our two layer inversion approach of computing the lithospheric complement. In Fig. S1, the current lithospheric complement approach (solid curve) fits well with the SKS splits, while the simple method (dashed curve) fitting is off at some stations.

References

Estey, L. H., Douglas, B. J., 1986. Upper mantle anisotropy: A preliminary model. J. Geophys. Res. 91 (B11), 11393.

Silver, P. G., Savage, M. K., 1994. The Interpretation of Shear-Wave Splitting Parameters In the Presence of Two Anisotropic Layers. Geophys. J. Int. 119 (3), 949–963.

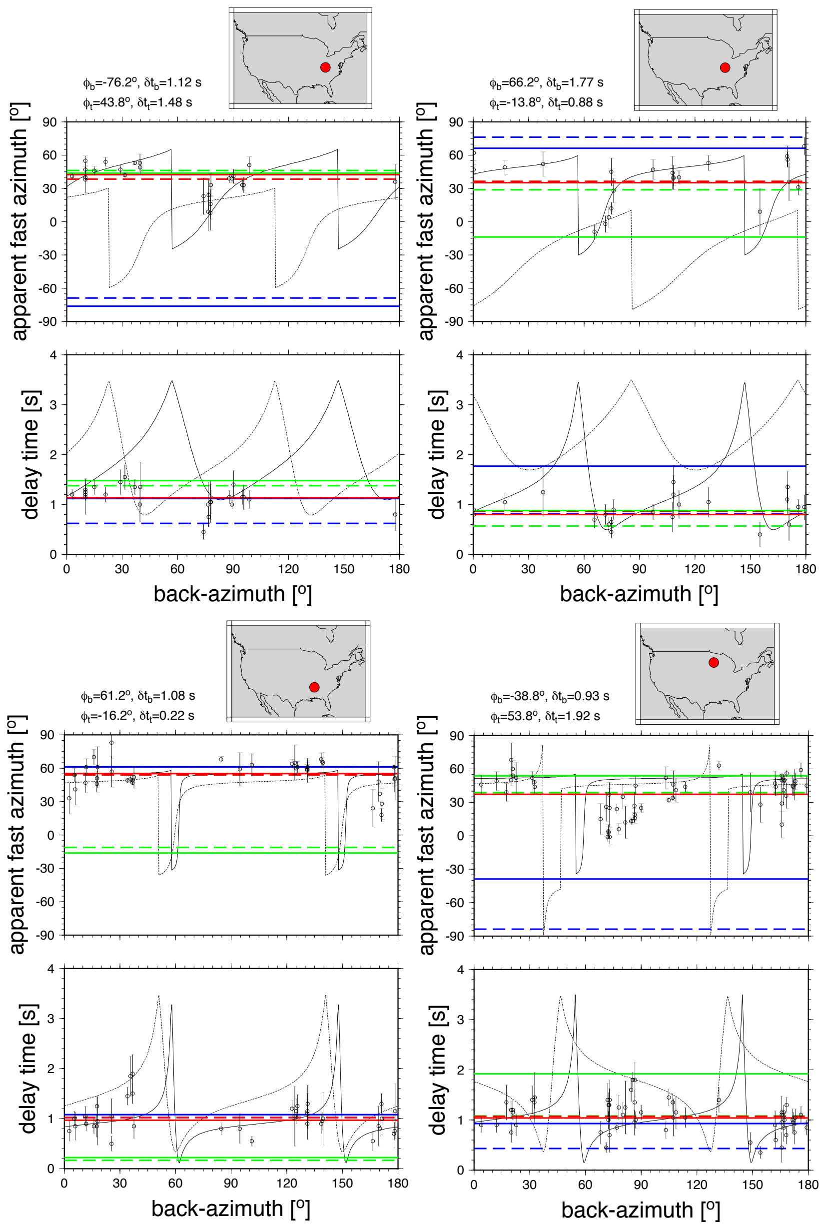

Figure S1: Examples of statistics at stations showing the shear wave splitting (SWS) two-layer inversion results, and the flow model (Model 5) hypothetical two layer anisotropy (top layer: flow model predicted anisotropy, and bottom layer: the hypothetical lithospheric complement). Caption continues on next page.

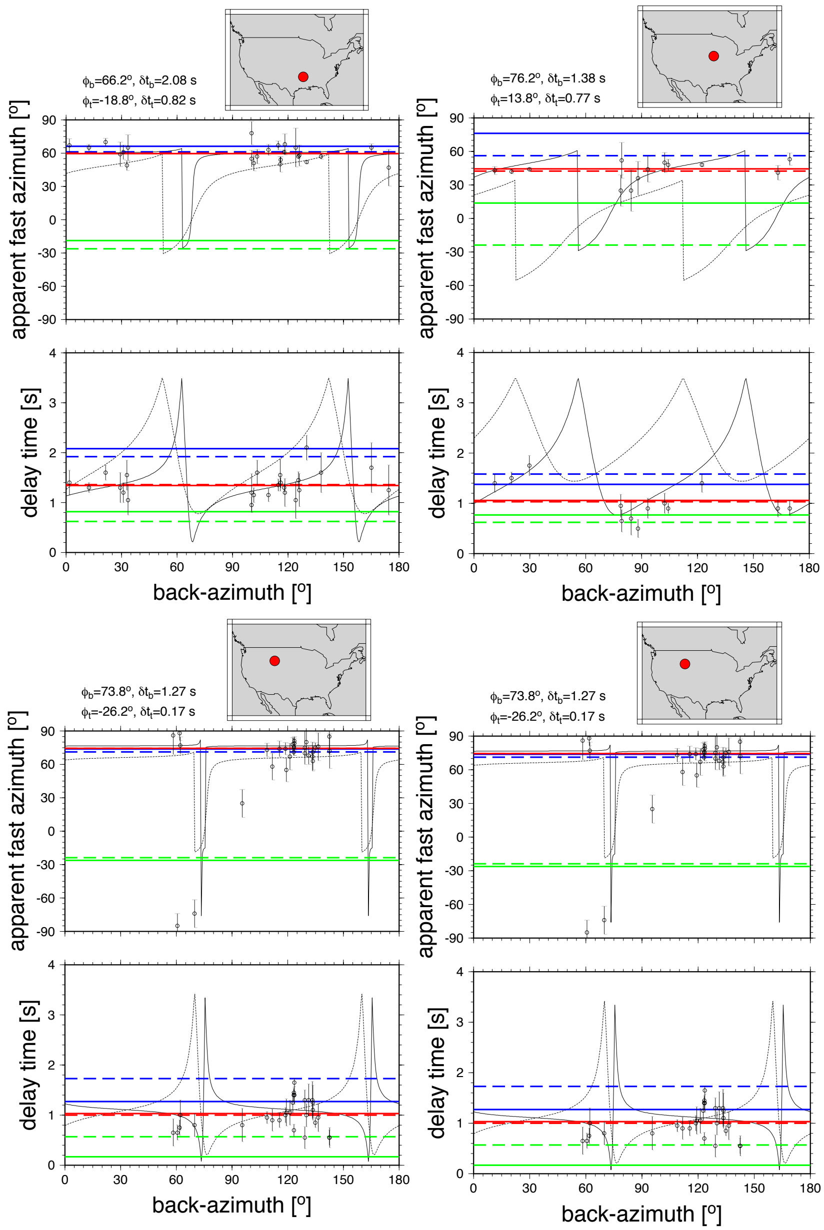

Figure S1: Continues from last page. The average values of the SWS top layer, bottom layer, and station average are shown by the solid blue line, solid green line, and solid red line, respectively. The average values of the top layer, bottom layer, and station average from the hypothetical two layer anisotropy are shown by the dashed blue line, dashed green line, and dashed red line, respectively. Caption continues on next page.

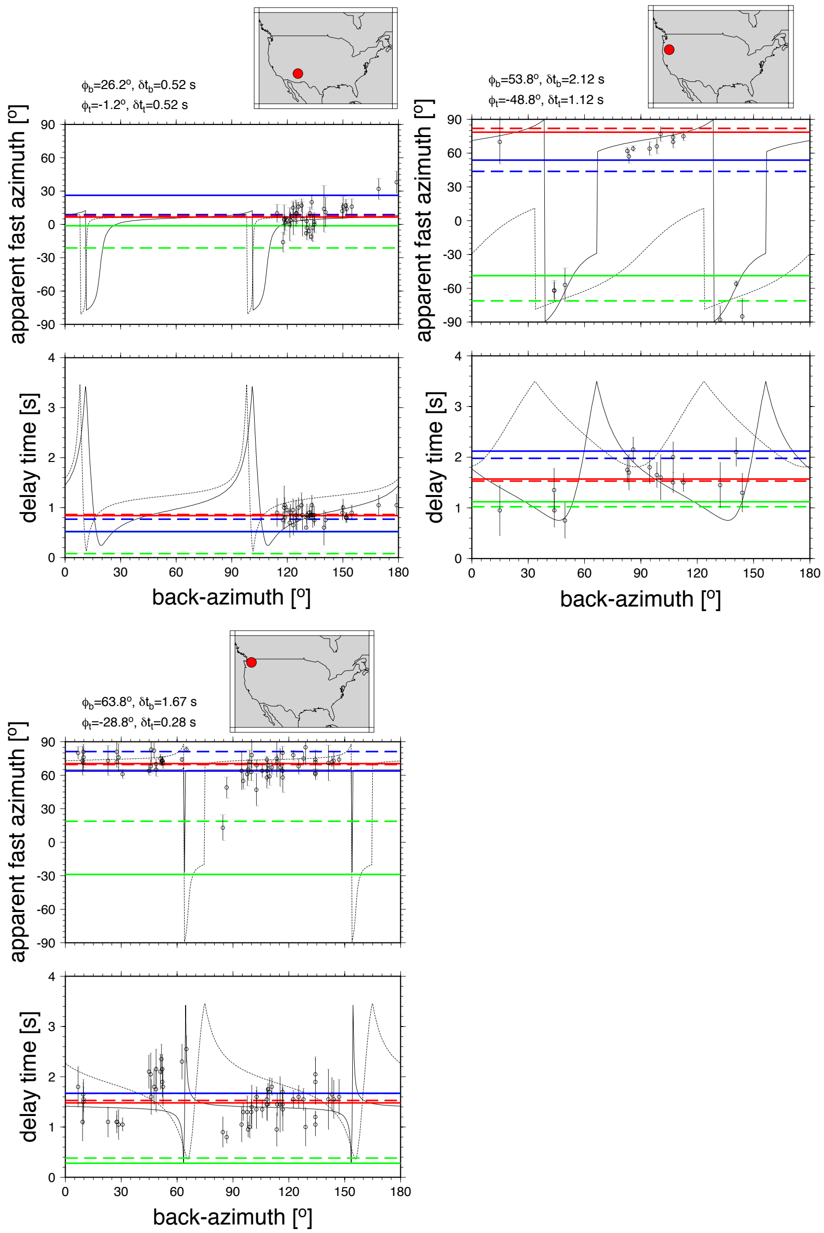

Figure S1: Continues from last page. Splitting parameters from SWS are shown by the black circles, and the vertical lines through the circles show estimated errors. The solid black curve shows the two-layer fitting of the hypothetical two layer anisotropy. The dashed black curve shows the two layer fitting for the simple method of computing lithospheric complement. The location of each station is shown by red dot on the map.

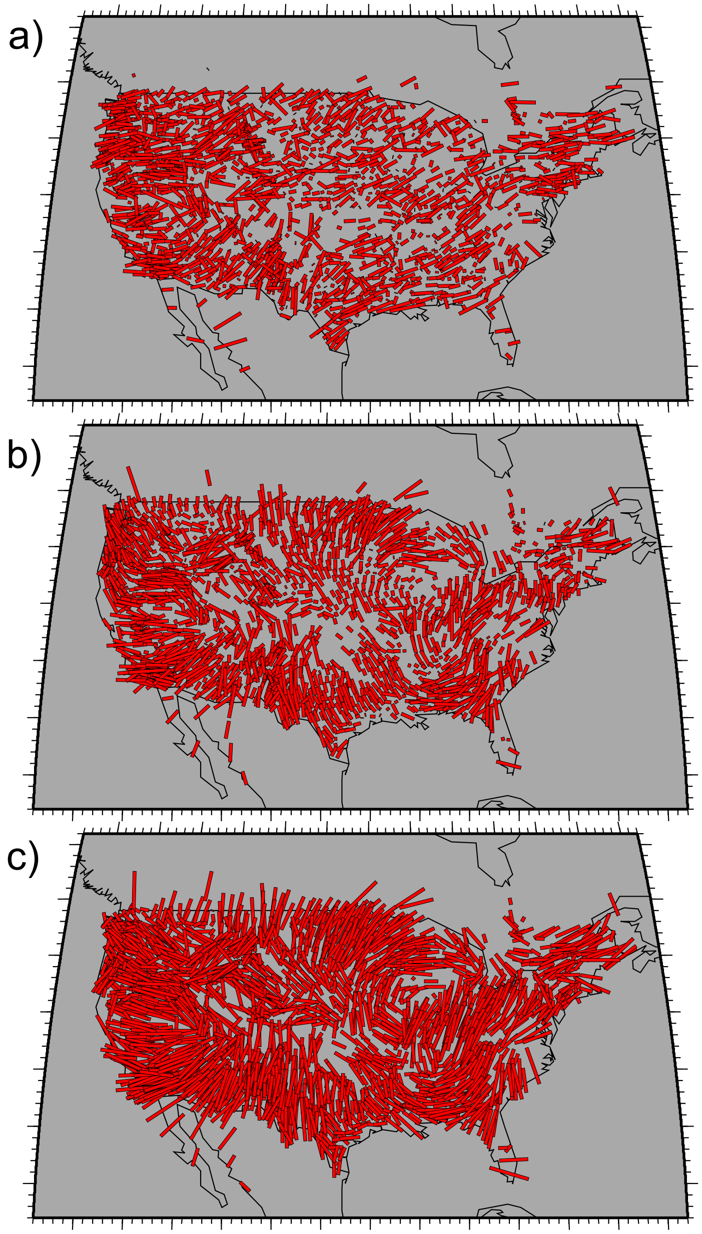

Figure S2: The top-layer anisotropy from a) station by station SWS two-layer inversion, b) method used for the main text of computing the lithospheric complement, and c) the simple method of computing lithospheric complement based on modeling average angles.