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SKS and SPdKS Sensitivity to Two-dimensional Ultra-low Velocity Zones.

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Introduction

This electronic data supplement contains a description of the approach used to identify the various seismic phases in our synthetic data sections, as well as a large selection of seismic waveform modeling results for various ULVZ models.

Phase identification was performed by first identifying primary seismic phases resulting from the interaction between an SKS wave and the CMB for overlying models consisting of PREM, 1-D ULVZs, and 2-D ULVZs (Supplemental Figure 1). The estimated arrival time for all of these phases was then calculated using the TauP toolkit (Crotwell et al., 1999), and corresponding travel time curves were overlain on the trace sections for phase identification (see example in Supplemental Figure 2).

Although the term ULVZ (Ultra-Low Velocity Zone) refers to structures exhibiting anomalous seismic velocities, some interpretations suggest that they might also be associated with positive density anomalies. To address this possibility, we ran a series of models to evaluate the effects that density perturbations in the ULVZ would have on the characteristics of the signal used in our analysis - namely the SKS waveform, the SPdKS waveform, and the SPdKS delay. An example of this modeling exercise is shown in Supplemental Figure 3, which compares trace sections produced for 40 km-thick ULVZs (1-D and 2-D) with and without density anomalies. We observe that density perturbations in the ULVZ do not cause any significant variations in the signals analyzed for the distance range, time window, and frequency band considered in this study. Therefore, we leave density constant and only consider velocity perturbations for the remainder of the study.

A large selection of modeling results for uniform and one-sided ULVZs are presented in Supplemental Figure 4. Results for finite-length ULVZs are shown in Supplemental Figure 5 (variable length, centered on the Pdiff inception point) and in Supplemental Figure 6 (finite length, covering different portions of the Pdiff segment).

1. 2009jbXXXXXX-fs01-1.eps (Supplemental Figure 1) Phase nomenclature and corresponding schematic ray-theoretical representation. In each panel, the solid line denotes the surface, the dashed line denotes the CMB, grey bands represent ULVZ's, and the dash-dot line denotes the top of the ULVZ's. Ray paths from the source (red star) to the station (green triangle) comprise elements of S-waves (red lines) and P-waves (blue lines in the mantle, cyan lines in the outer core).

2. 2009jbXXXXXX-fs01-2.eps (Supplemental Figure 1-continued)

3. 2009jbXXXXXX-fs02.eps (Supplemental Figure 2) Phase identification. Panels show pseudospectral SV displacement seismograms for three categories of CMB velocity models. Left column: PREM. Middle column: a 40 km-thick, 1-D ULVZ with 10% P and 30% S-velocity reduction. Right column: a 40 km-thick, source-side ULVZ with 10% P and 30% S-velocity reduction. Top row shows the raw seismogram sections. Bottom row shows seismogram sections with TauP predicted arrival times for a variety of phases
resulting from the interaction of SKS with the different models (see Supplemental Figure 1 for phase nomenclature). Yellow dashed line indicate predicted arrival times for sPPP, PPPP, pPPP and other multiple P arrivals. Other phases are listed in the legends of each panels.

4. 2009jbXXXXXX-fs03.eps (Supplemental Figure 3) Effects of density perturbations. Comparison of synthetic data sections produced for models without (left column) and with (right column) density perturbations in the ULVZ. Density perturbations are modeled by increasing the density by 10% over PREM values in the ULVZ. Top row: 40 km-thick, 1-D ULVZ with 10% P and 30% S-velocity reduction. Bottom row: 40 km-thick, source-side ULVZ with 10% P and 30% S-velocity reduction. Colored lines denote manual phase picks. Solid blue line: PREM SKS arrival. Solid red line: PREM SPdKS arrival. Green lines (solid and dashed): SPdKS arrivals for ULVZs without any density anomaly. Magenta line (solid and dashed): SPdKS arrivals for ULVZs with 10% density anomaly. Yellow dashed line

indicate predicted arrival times for sPPP, PPPP, pPPP and other multiple P arrivals.

5. 2009jbXXXXXX-fs04-1.eps (Supplemental Figure 4) Synthetic seismograms produced by running the pseudospectral seismic wave propagation code on the 1-D, 10% P and 30% S-velocity reduction ULVZ velocity models (Figure 5a in the paper), the source-side ULVZ velocity models (Figure 5b in the paper), and PREM [Dziewonski and Anderson, 1981]. The solid blue line shows the PREM SKS arrival and the solid red line shows the PREM SPdKS arrival. On 1-D ULVZ plots, the solid green line shows the SPdKS picks for that model. On the one-sided ULVZ plots, dashed red lines show the SPdKS picks for the one-sided model and the solid green line repeats the SPdKS for the equivalent 1-D model. Yellow dashed line indicate predicted arrival times for sPPP, PPPP, pPPP and other multiple P arrivals.

6. 2009jbXXXXXX-fs04-2.eps (Supplemental Figure 4-continued)

7. 2009jbXXXXXX-fs05-1.eps (Supplemental Figure 5) Synthetic seismograms for ULVZs of different lengths and thicknesses, with ULVZs centered on the Pdiff inception point (Figure 5d in the paper). All ULVZs have 10% P and 30% S-velocity reduction. Blue line shows SKS picks from PREM pseudospectral synthetic seismograms. Solid red line shows PREM SPdKS picks. Dashed red line shows SPdKS picks for every given model. Solid magenta lines show SPdKS picks for equivalent one-sided ULVZ model. Yellow dashed line indicate predicted arrival times for sPPP, PPPP, pPPP and other multiple P arrivals.

8. 2009jbXXXXXX-fs05-2.eps (Supplemental Figure 5-continued)

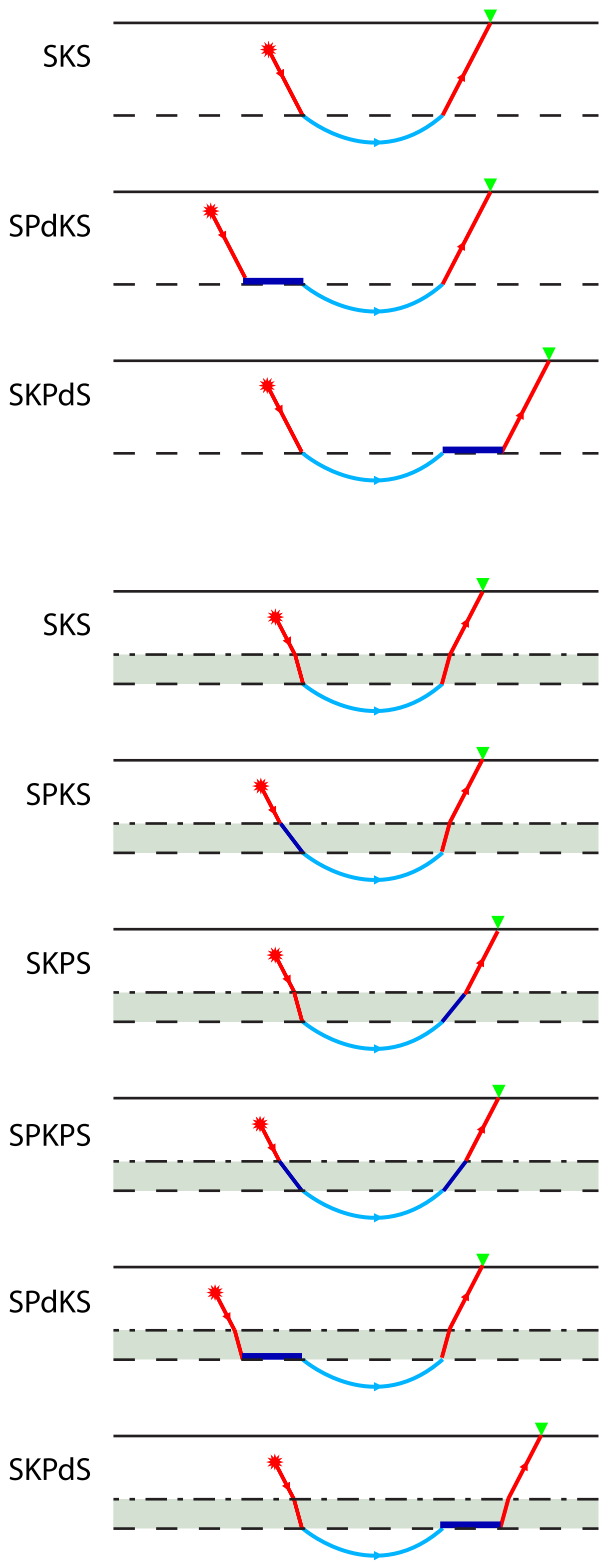
9. 2009jbXXXXXX-fs05-3.eps (Supplemental Figure 5-continued)

10. 2009jbXXXXXX-fs05-4.eps (Supplemental Figure 5-continued)

11. 2009jbXXXXXX-fs05-5.eps (Supplemental Figure 5-continued)

12. 2009jbXXXXXX-fs06-1.eps (Supplemental Figure 6) Synthetic seismograms for models of distal ULVZs (Figure 5e in paper) and proximal ULVZs (Figure 5f in paper). Blue line shows SKS picks from PREM pseudospectral synthetic seismograms. Solid red line shows PREM SPdKS picks. Dashed red line shows SPdKS picks for every given model. Solid magenta lines show SPdKS picks for equivalent one-sided ULVZ model. Yellow dashed line indicate predicted arrival times for sPPP, PPPP, pPPP and other multiple P arrivals.

13. 2009jbXXXXXX-fs06-2.eps (Supplemental Figure 6-continued)



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2-D ULVZs
Suppl. Figure 1
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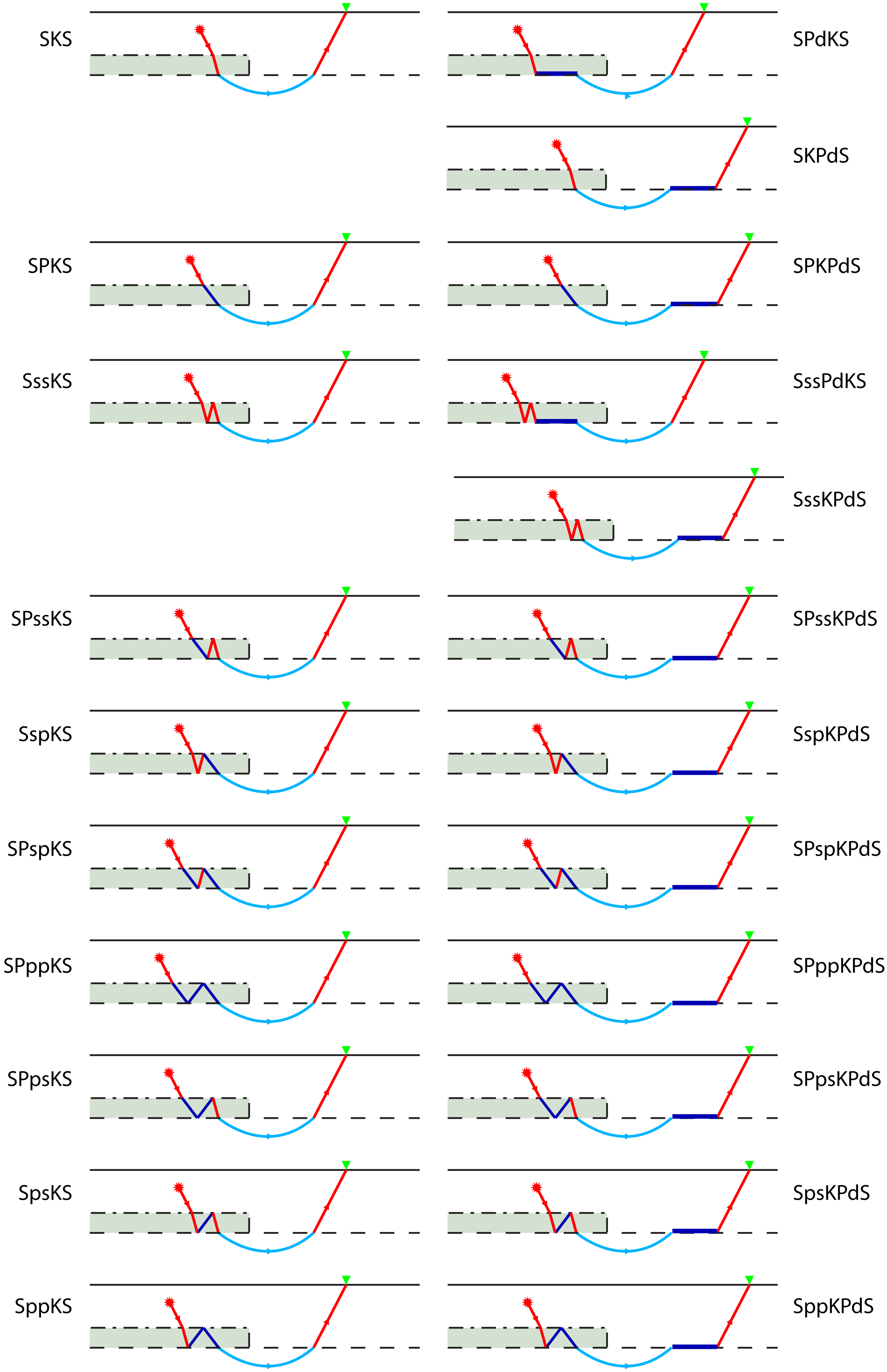

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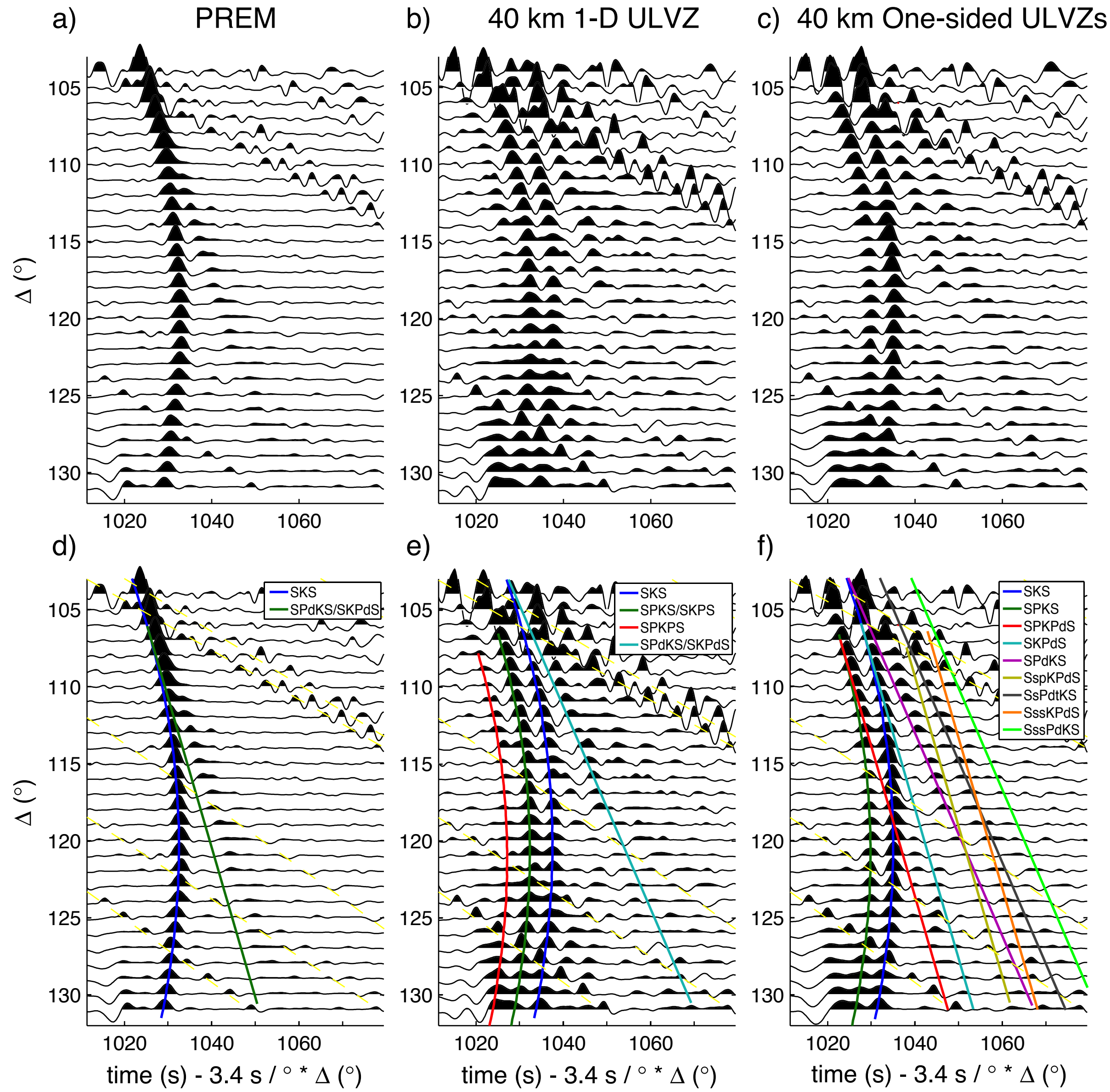

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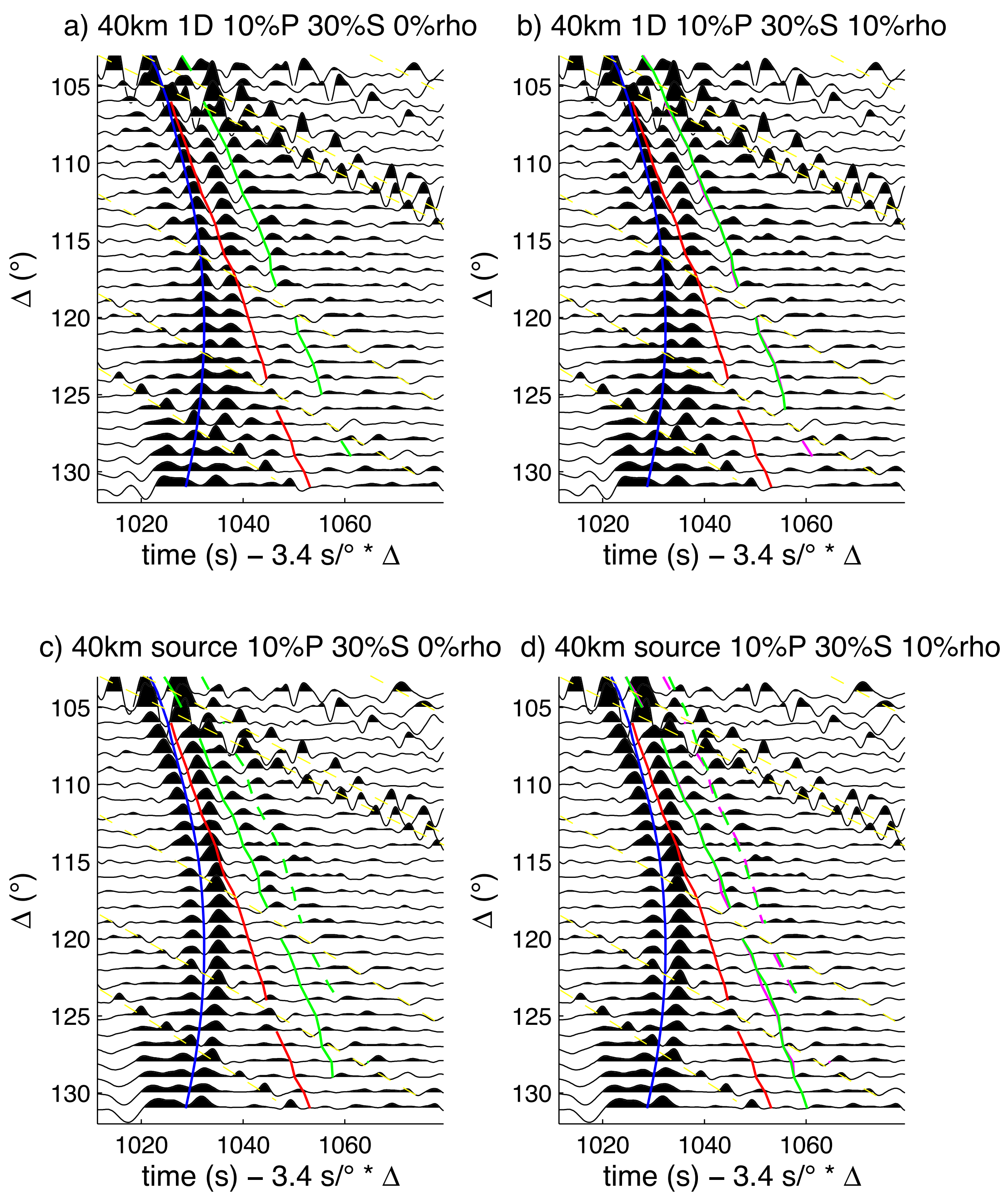

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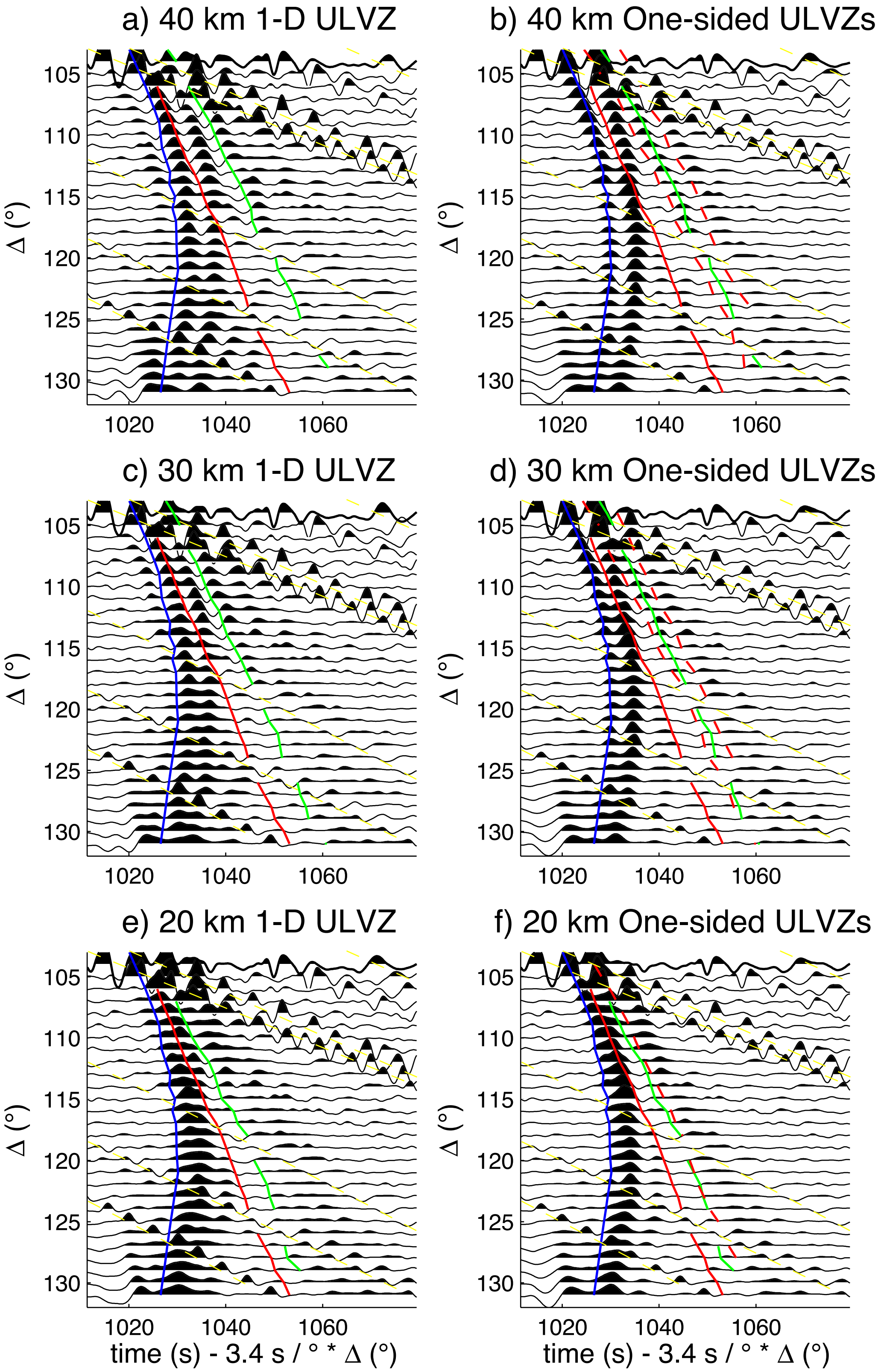
Suppl. Figure 3



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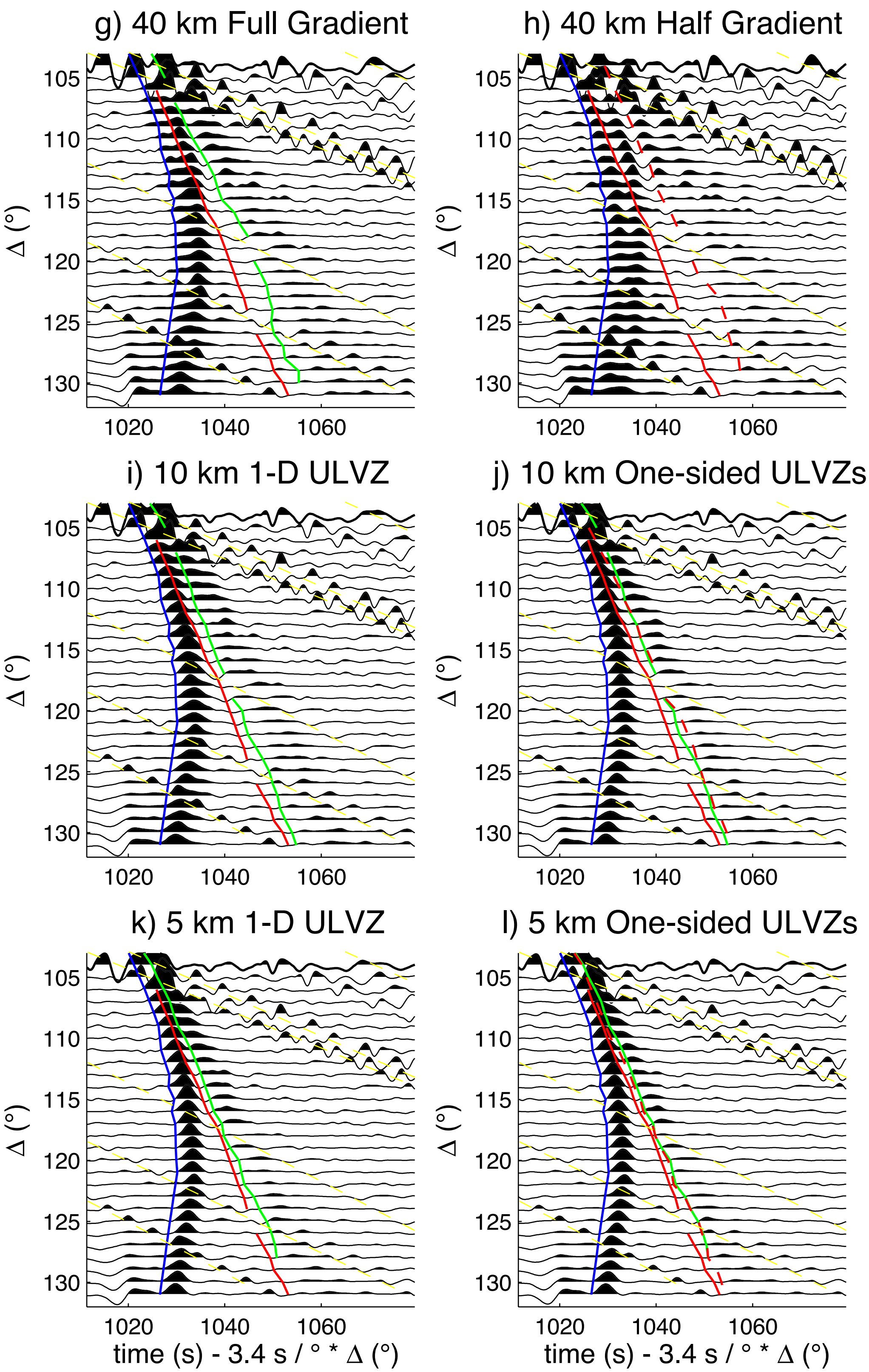

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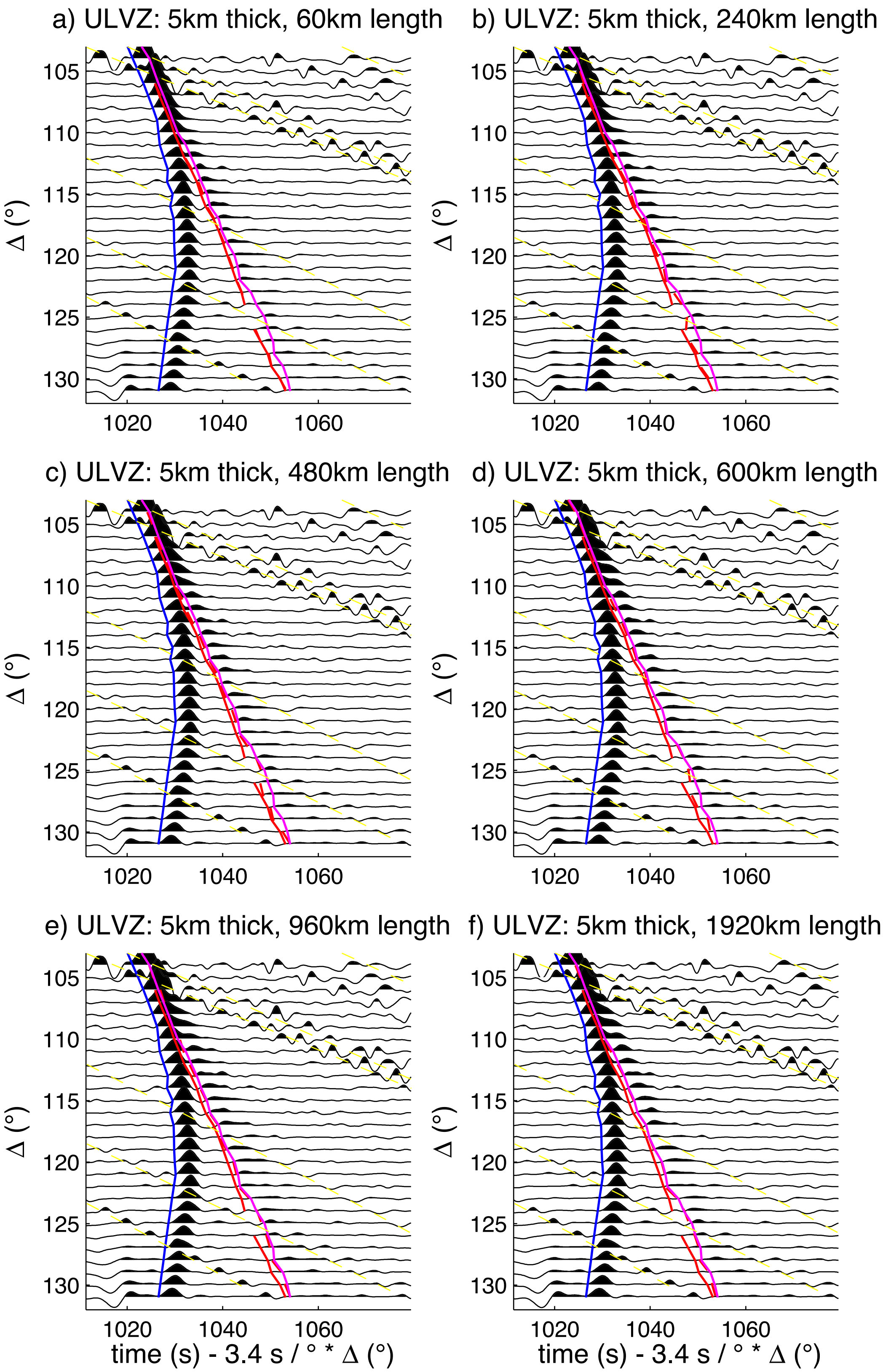

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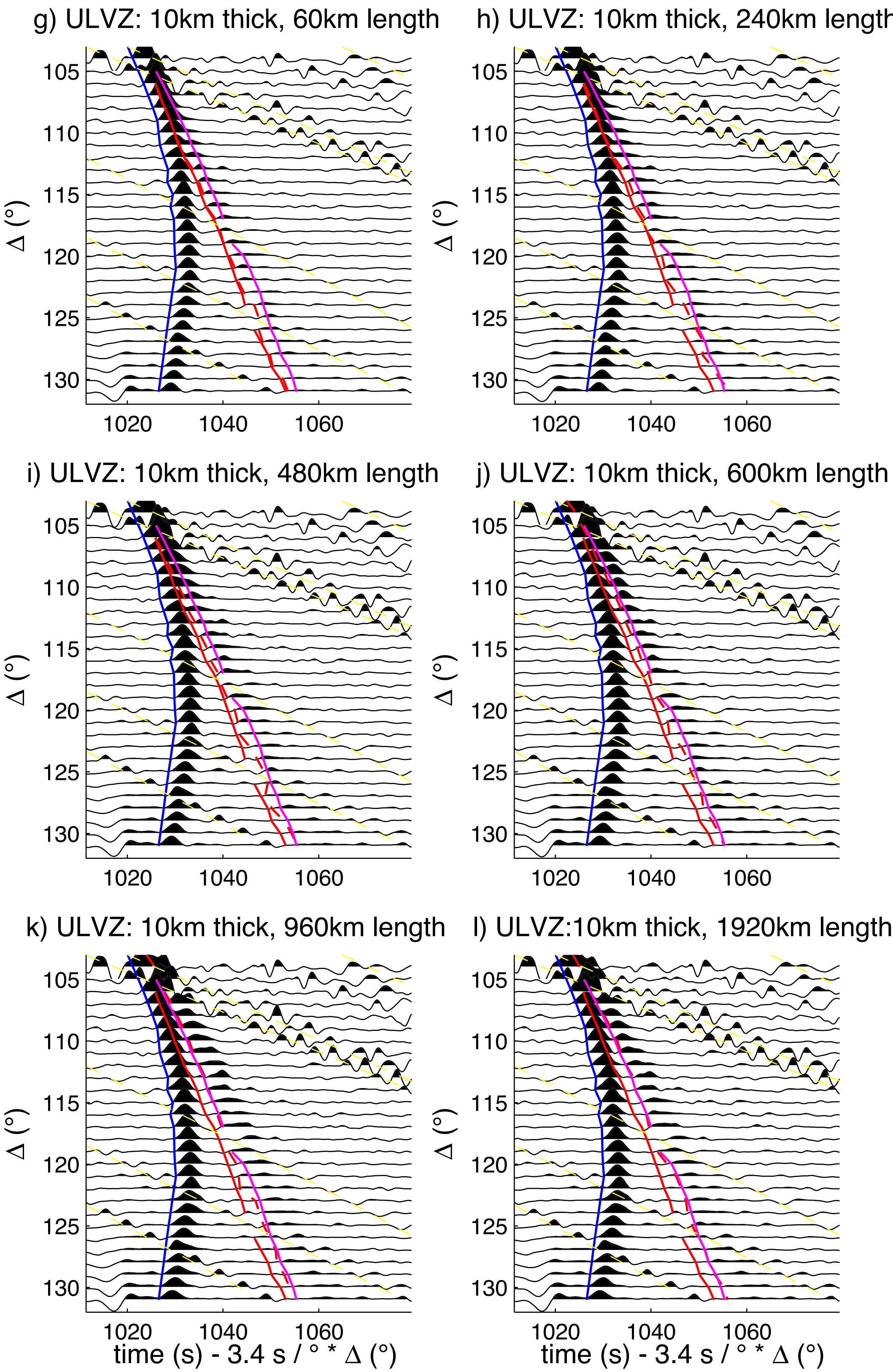

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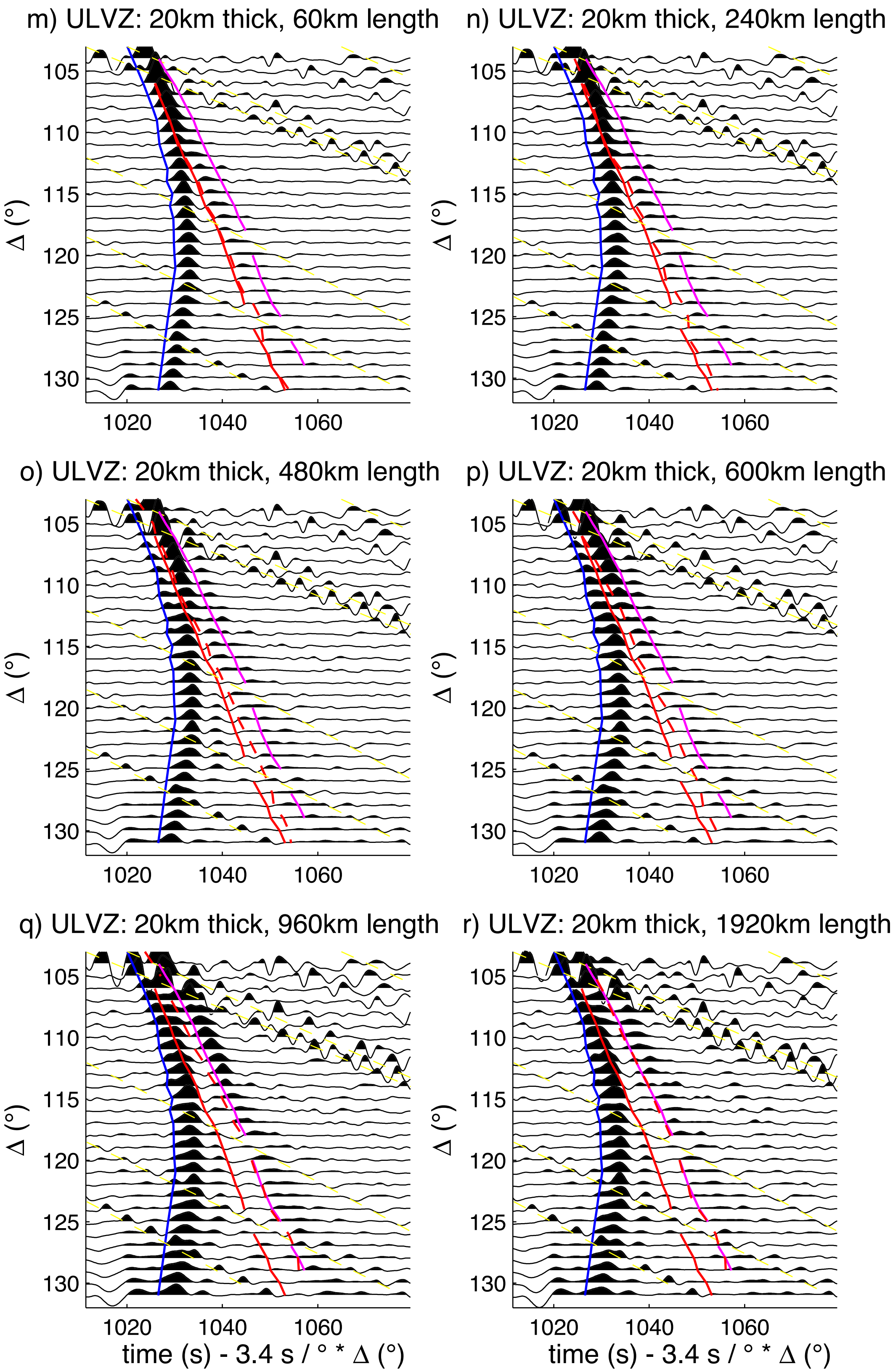

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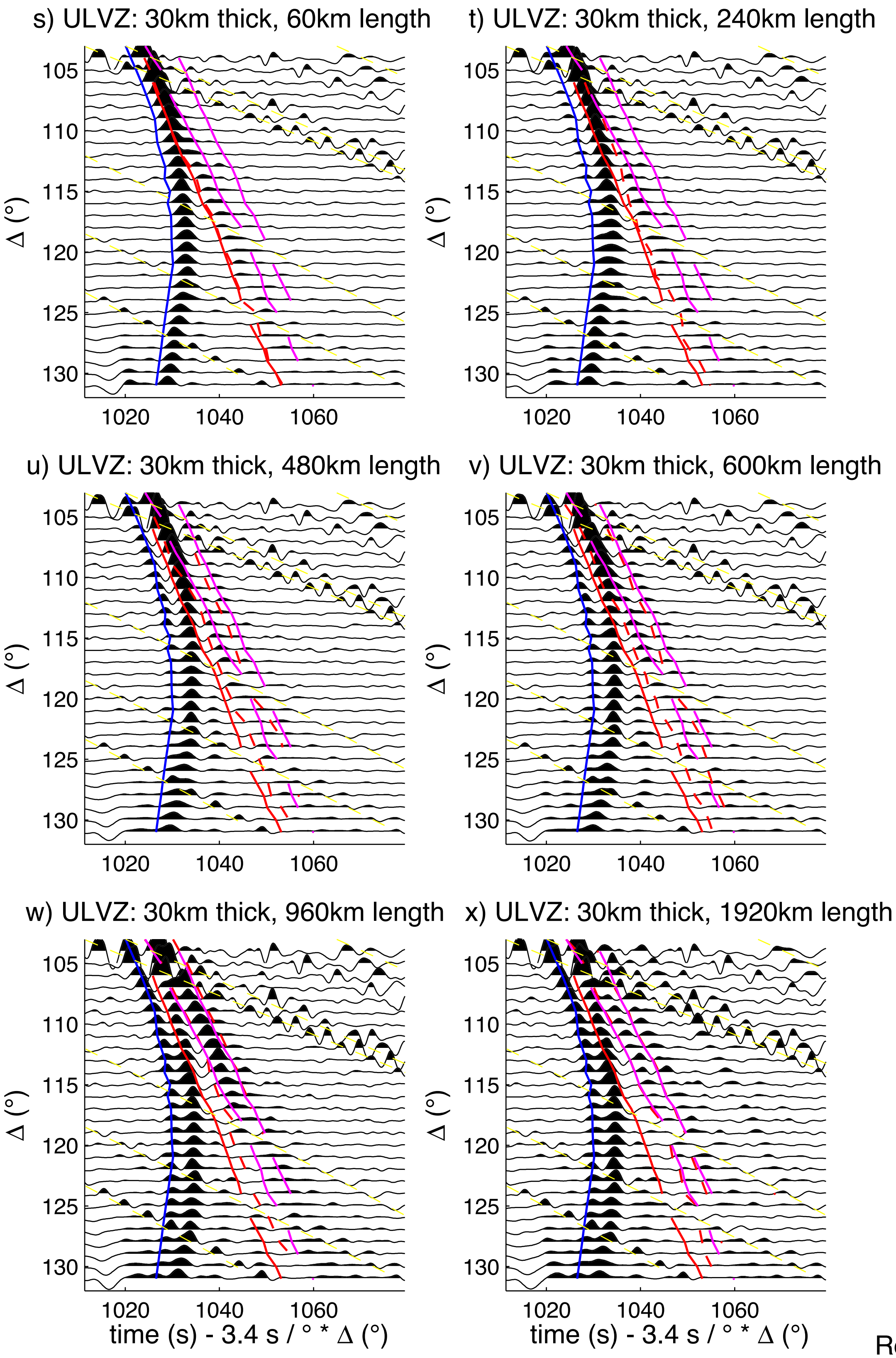

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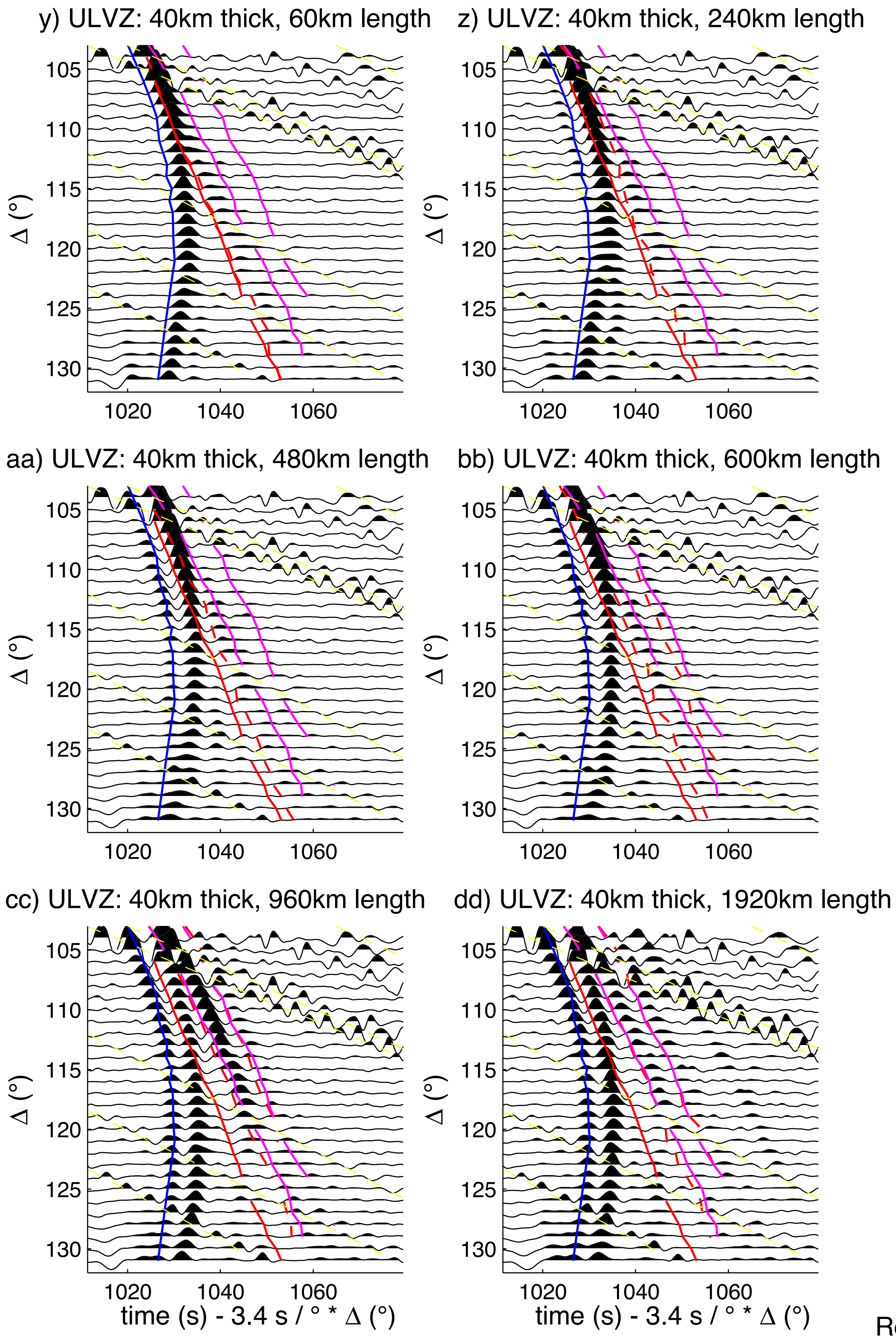

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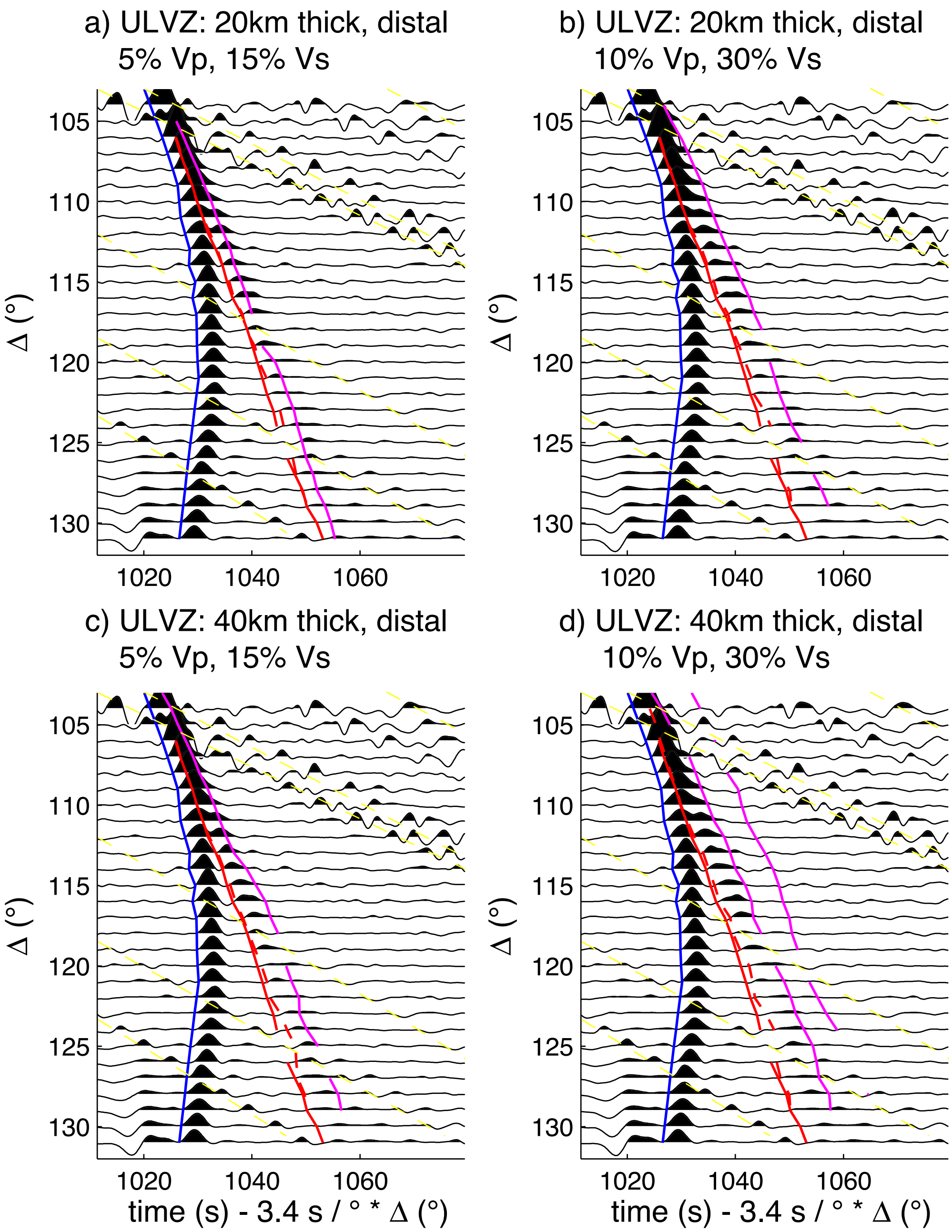

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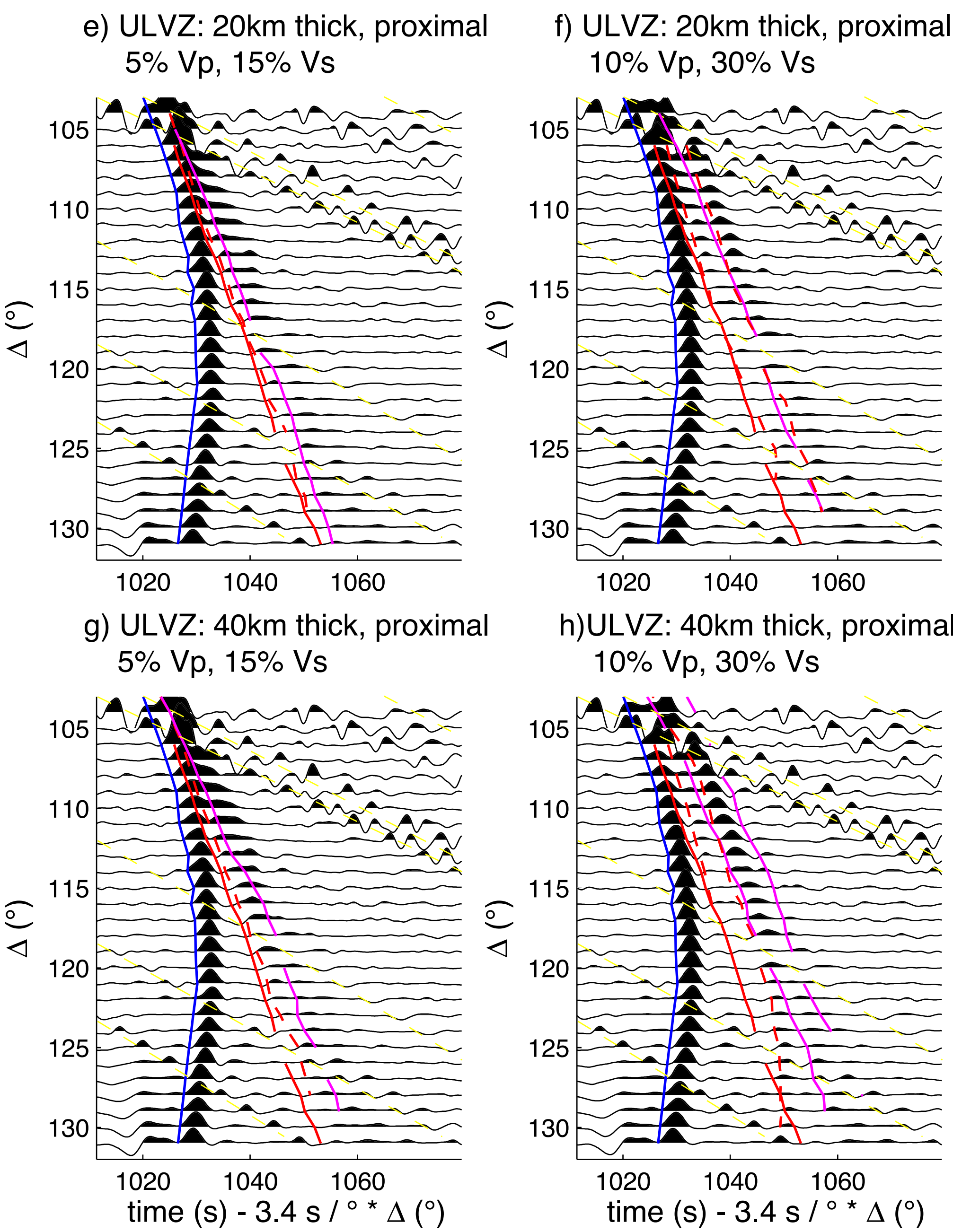

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