Data Repository:
Seismic and Geodetic Evidence For Extensive, Long-Lived Fault Damage Zones

Fault Zone Trapped Wave Data and Methods

Fault zone trapped waves observed for 2 shots and 5 local earthquakes (Table 1) are modeled using a 3D finite difference technique. The data are low-pass filtered at 1, 2, or 3 Hz depending on the dominant period of the trapped waves. The model has a grid spacing of 0.0625 km. The parameters used to model the fault are: the fault width is 1.5 km, the fault depth is 12 km, and the shear-wave velocity reduction is 50%. Note that the low velocity zone is tapered linearly with depth giving an effective fault depth of about 5 km.

The depth of the low velocity zone (LVZ) is constrained by the deepest earthquake, local earthquake 200616317, which is located at an epicentral distance of 28 km and a depth of 11 km. Figure 1 shows a comparison of the data and synthetic waveforms computed for a LVZ that extends to 12 km depth and a LVZ that extends to only 3 km depth. It is clear that a 3 km deep LVZ does not sufficiently replicate the extended fault zone trapped waves observed in the data.

Travel Time Data and Methods

We use shots, local earthquakes, and teleseismic P-wave arrivals to model the fault zone properties (Table 2). The P-arrivals for the shots and local events were picked by hand as the arrivals were fairly impulsive and delay times were significant. Teleseismic P-wave arrivals were determined by cross-correlation. Figure 2 shows P arrivals for event 200627213 across line B, before and after cross-correlation delays are applied.

To compute the travel times we use the graph theory technique of *Moser* (1991), modified as described in *Nolet et al.* (2005). Graph theory is based on the formulation of the shortest path through a network. Graph theory generates ray paths that are more accurate than traditional ray tracing methods and allows for unrestricted complexity or dimensionality of the velocity model. We model a range of fault parameters, modifying the velocity reduction, fault width, fault depth, and velocity taper across the fault and with depth. Fault width and velocity reduction are not fully independent, so slight variations in fault width and velocity reduction will give similar misfits. Figure 3 shows a comparison for different fault widths, given a velocity reduction of 40% and fault depth of 12 km. It is clear that fault widths less than 1 km do not fit the data well.

Comparison of the InSAR and Seismic Data.

Models of permanent deformation due to coseismc stress changes allow us to constrain reduction in λ and μ, the Lamé parameters, within the fault zone, and directly compare the elastic structure that fits the InSAR data with the seismically inferred P-wave and S-wave velocities. The best fitting InSAR model has variations in the elastic properties assuming a Poisson solid, such that μ is reduced by 65% and λ is reduced by 30% within the fault zone. In terms of velocities, this would suggest a P-wave velocity reduction of about 30% and an S-wave velocity reduction of 40%. Both the trapped wave data and the P-wave travel times suggest slightly higher velocity reductions within the low velocity zone, although the seismic data (fault zone trapped waves and travel times) do not constrain the velocities much better than ± 10%. We use an S-wave velocity reduction of 50% for the trapped wave synthetics and a velocity reduction of 40% to model the P-wave travel times. The geometries used to model the fault are the same in all three cases, with a fault width of 1.5 km and a fault depth of 12 km. The velocities are graded to background values away from the fault using a Hanning taper away from the fault slip plane and a linear taper with depth, as described in the main text.

Table 1. Fault Zone Trapped Wave Data. Distance is the epicentral distance in kilometers between the center of the seismic array (34.604, -116.477) and an event.

Event ID	Type	Magnitude	Latitude	Longitude	Depth	Distance
200615714	Shot	n/a	34.661	-116.536	0.0	8.4
200615717	Shot	n/a	34.597	-116.470	0.0	1.0
200616317	Local Earthquake	1.0	34.406	-116.290	10.8	27.9
200616813	Local Earthquake	1.1	34.587	-116.450	4.1	3.1
200626506	Local Earthquake	1.1	34.496	-116.349	3.4	16.8
200628602	Local Earthquake	1.5	34.876	-116.712	3.3	37.1
200632306	Local Earthquake	1.6	34.491	-116.328	3.2	18.6

Table 2. Travel Time Data. Distance is the epicentral distance between the center of the seismic array (34.604, -116.477) and an event. Distance is given in kilometers for shots and local earthquakes and distance is given in degrees for teleseismic earthquakes.

Event ID	Type	Magnitude	Latitude	Longitude	Depth	Distance
200615714	Shot	n/a	34.661	-116.536	0.0	8.4
200615715	Shot	n/a	34.635	-116.562	0.0	8.5
200615717	Shot	n/a	34.597	-116.470	0.0	1.0
200615511	Local Earthquake	1.4	34.816	-116.422	4.1	12.0
200615516	Local Earthquake	1.4	34.463	-116.234	8.1	27.2
200615621	Local Earthquake	1.0	34.488	-116.506	3.8	13.2
200615717	Local Earthquake	2.5	34.629	-116.657	6.4	16.7
200615721	Local Earthquake	1.2	34.705	-116.292	4.7	20.3
200616119	Local Earthquake	1.4	34.614	-116.667	8.2	17.4
200616317	Local Earthquake	1.0	34.406	-116.290	10.8	27.9
200618204	Local Earthquake	0.8	34.693	-116.330	12.0	16.7
200620405	Local Earthquake	1.3	34.506	-116.521	12.5	11.6
200620512	Local Earthquake	1.1	34.495	-116.461	11.2	12.2
200620803	Local Earthquake	1.2	34.780	-116.467	13.5	19.6
200620814	Local Earthquake	1.3	34.591	-116.629	8.1	14.0
200620819	Local Earthquake	1.9	34.444	-116.782	2.6	33.1
200621021	Local Earthquake	1.9	34.639	-116.665	6.3	17.7
200623307	Local Earthquake	1.2	34.550	-116.302	5.6	17.1
200626914	Local Earthquake	1.2	34.957	-116.536	3.2	39.7
200627905	Local Earthquake	1.1	34.767	-116.388	3.8	19.9
200628602	Local Earthquake	1.5	34.876	-116.712	3.3	37.1
200629617	Local Earthquake	1.5	34.468	-116.517	9.8	15.6
200630603	Local Earthquake	0.8	34.626	-116.203	15.8	25.2
200616918	Teleseism	5.9	32.970	-39.714	10.0	62.2°
200618920	Teleseism	6.6	51.259	-179.285	50.8	47.3°
200621818	Teleseism	5.8	26.091	144.035	23.1	82.7°
200624412	Teleseism	5.9	53.997	-166.366	78.1	39.5°
200627106	Teleseism	6.9	-16.613	-172.035	28.0	73.5°
200627213	Teleseism	6.1	10.910	-61.650	53.0	55.0°
200628817	Teleseism	6.7	19.878	-155.935	38.9	37.8°
200631701	Teleseism	6.8	-26.038	-63.243	547.5	78.9°

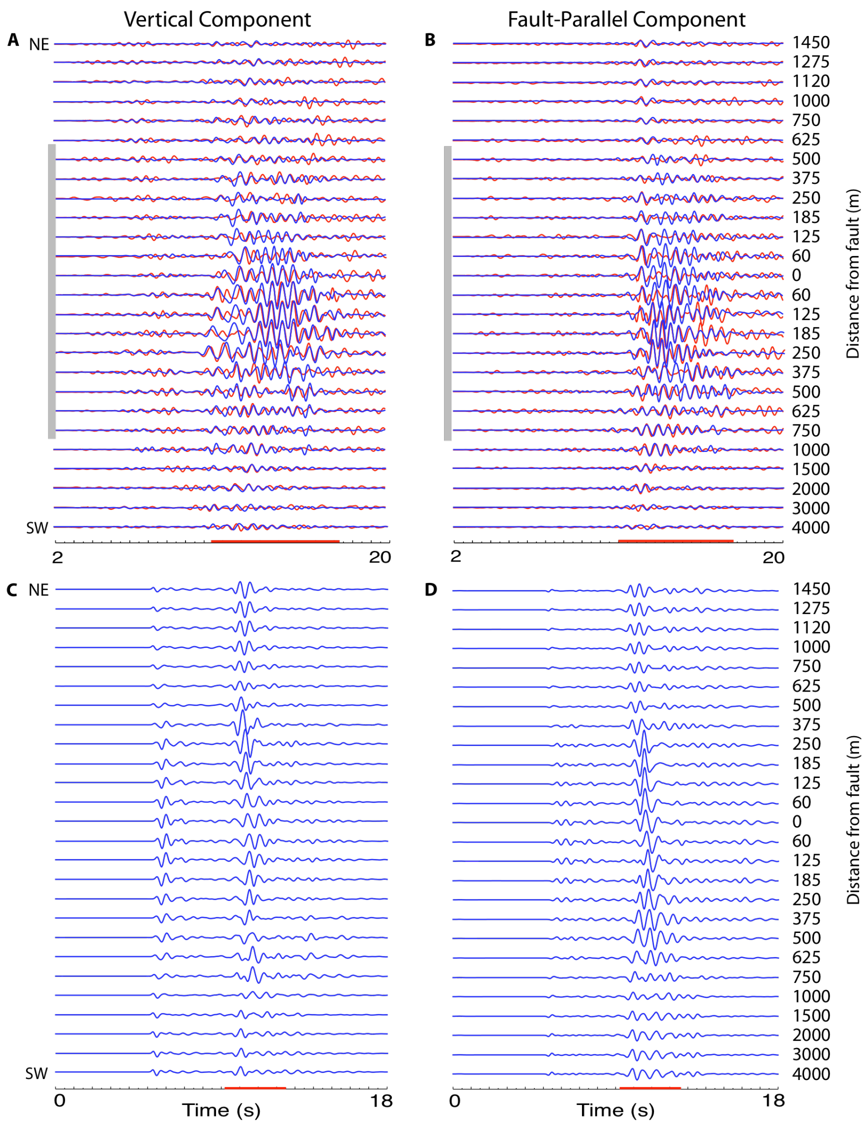

Figure 1. Fault Zone Trapped Wave Depth Dependence. Sensitivity of fault zone trapped waves to low velocity zone depth. **(A)** Actual (red) and synthetic (blue) vertical seismograms for local event 200616317. The red bar on the X-axis indicates the approximate location of the fault zone trapped waves. The width of the compliant zone is shown by the vertical grey bar on the Y-axis. Synthetic seismograms were computed using the model shown in Fig 4 and described in the text with a low velocity zone depth of 12 km. **(B)** Actual (red) and synthetic (blue) fault-parallel seismograms for local earthquake 200616317 **(C)** Actual (red) and synthetic (blue) vertical seismograms for local earthquake 200616317 for the same model as in (a) and (b) except with a low velocity zone depth of 3 km. (**D**) Actual (red) and synthetic (blue) fault-parallel seismograms for local earthquake 200616317 for the same model as in (a) and (b) except with a low velocity zone depth of 3 km. See Table 1 for location information. Data are low pass filtered at 2 Hz.

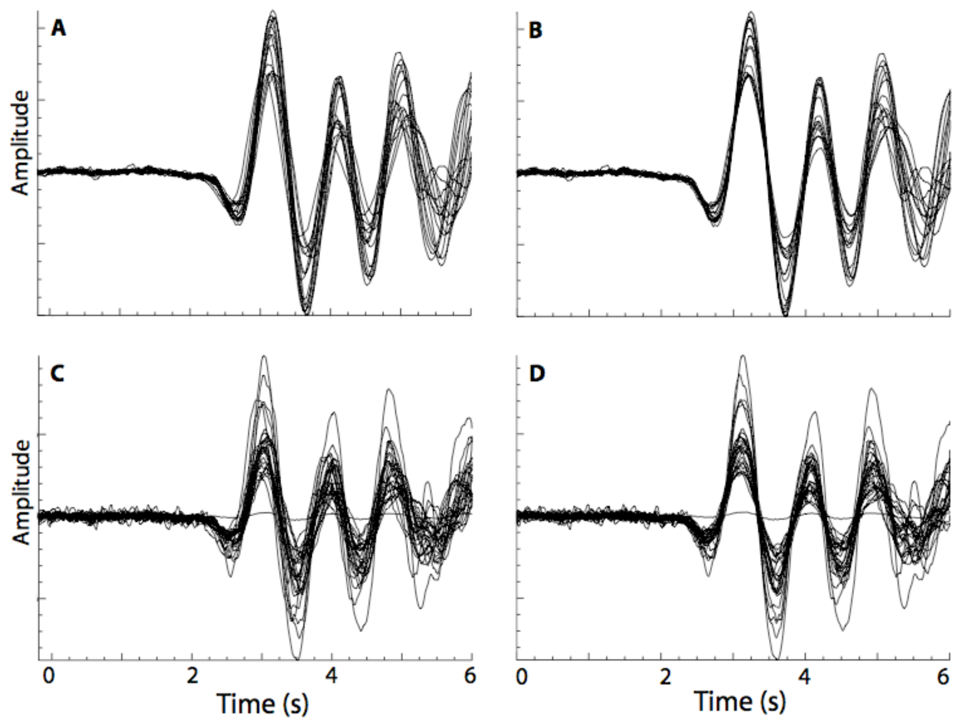

Figure 2. Travel Time Cross Correlation. Cross correlation of P-wave arrivals for teleseismic earthquake 200627213. **(A)** Intermediate period station (40T sensor) seismograms aligned using manual picks, **(B)** Intermediate period seismograms aligned using cross-correlation, **(C)** Short period station (L22 sensor) seismograms aligned using manual picks, **(D)** Short period seismograms aligned using cross-correlation.

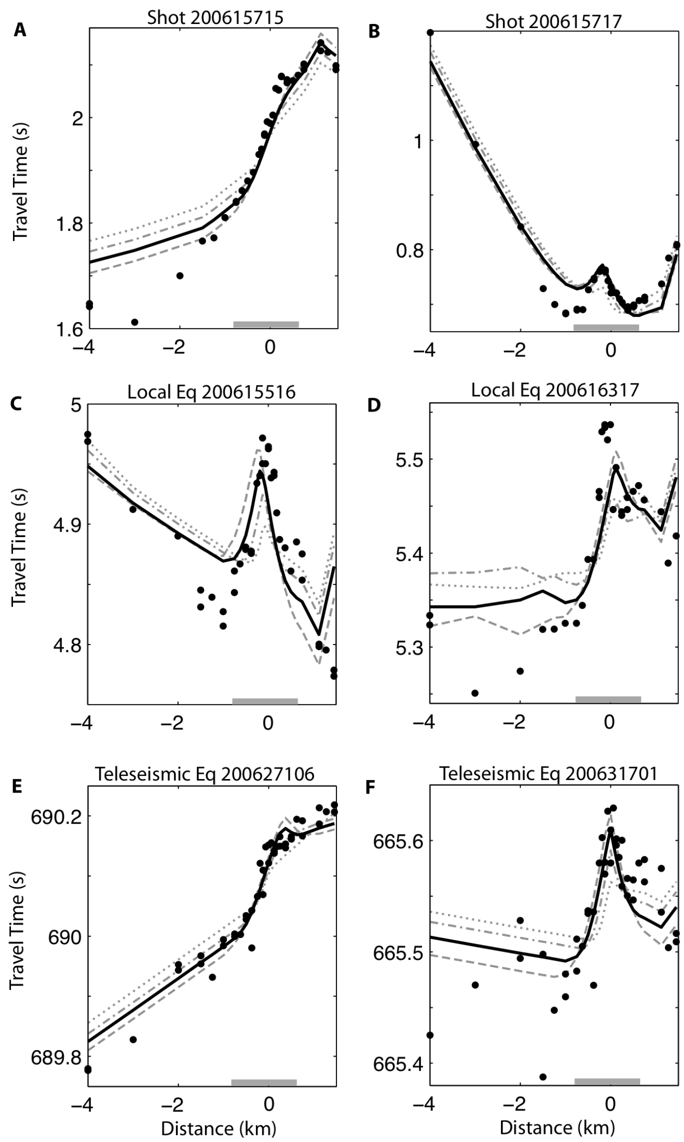

Figure 3. Low Velocity Zone Width Modeling. Predicted travel times for fault zone models with different low velocity zone widths (lines) to the actual travel times (points) across Line B. Velocity reduction is held constant at 40%. Models shown are 0.5 km wide low velocity zone, 1 km wide low velocity zone (dash-dot grey line), 1.5 km wide low velocity zone (solid black line), and 2 km wide low velocity zone (dashed grey line). Data are shown for events: **(A)** Shot 200615715, **(B)** Shot 200615717, **(C)** Local earthquake 200615516, **(D)** Local earthquake 200616317, **(E)** Teleseismic earthquake 200627106, and **(F)** Teleseismic earthquake 200631701. The approximate location of the low velocity zone is shown by the grey line along the X-axis. Event information can be found in Table 2.