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Empirical Green's Function Analysis of the Wells, Nevada, Earthquake Source

by

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ABSTRACT

We report the results of a finite-fault study of the 21 February 2008 Wells, Nevada earthquake conducted by Mendoza and Hartzell (2009, GRL v. 36, L11302) using regional broadband records for eight M_W 4 (approximate) aftershocks) to quantify the seismic response of point sources in the mainshock source region. These empirical Green's functions were used to generate synthetic records for 100 subfaults distributed over a 20-km by 20-km fault area assuming a rupture velocity of 2.8 km/sec. Three-component, velocity waveforms recorded at 46 different stations located within 300 km of the mainshock epicenter were then inverted to recover the contribution of coseismic slip required for each subfault. The inversion identifies a relatively compact, 6-km by 4-km source for the 2008 Wells earthquake with a maximum slip of 88 cm and an estimated stress drop of 72 bars. The total seismic moment is 6.2 x 10^{24}dyne-cm (5.8 M_W).

INTRODUCTION

The normal-faulting earthquake of 21 February 2008 northeast of Wells, Nevada was recorded by several permanent broadband stations of the Advanced National Seismic System (ANSS) and by numerous portable broadband stations of the EarthScope Transportable USArray (figure 1). These stations also recorded many of the aftershocks, offering an unprecedented opportunity for using empirical Green's functions (EGFs) to account for propagation effects in the study of the earthquake source. Mendoza and Hartzell (2009) used these regional data to derive a source model for the Wells earthquake using the observed aftershock records to quantify the seismic response of point sources near the earthquake source region. We summarize the results obtained by Mendoza and Hartzell (2009) using this EGF approach.

INVERSION METHOD AND ANALYSIS

The rupture history of the Wells earthquake was recovered using the kinematic, finite-fault inversion procedure of Hartzell and Heaton (1983). In the analysis, a SE-dipping, 20-km by 20-km fault plane oriented NE (N36°E strike; 44°dip) was placed in the earthquake source region and subdivided into 100 distinct 2-km by 2-km subfaults. The fault depth extends from 1 to 16 km with rupture propagating radially from the hypocenter placed at a depth 7.2 km. The response of each subfault at each recording site was then calculated by summing empirical Green's functions (EGFs) for evenly-spaced points on the fault, delayed by times corresponding to a fixed rupture velocity of 2.8 km/sec. EGFs were assigned from a suite of observed aftershock recordings based on the location of the nearest aftershock along the fault, scaled from its original magnitude to a common moment. The observed mainshock records were then inverted using positivity, spatial-smoothing, and moment-minimization constraints to identify the amount of slip required of each subfault to reproduce the observations. Three-component, broadband velocity waveforms recorded within 300 km of the mainshock were included in the inversion using a record length of 80 sec. This time window includes body-and surface-wave energy recorded at the majority of the sites. A 0.02–0.5 Hz bandpass filter was applied to both the mainshock and aftershock records to coincide with the principal band of seismic energy recorded at the regional distances. Since all events were recorded by the same stations, it was not necessary to remove the effect of the instruments.

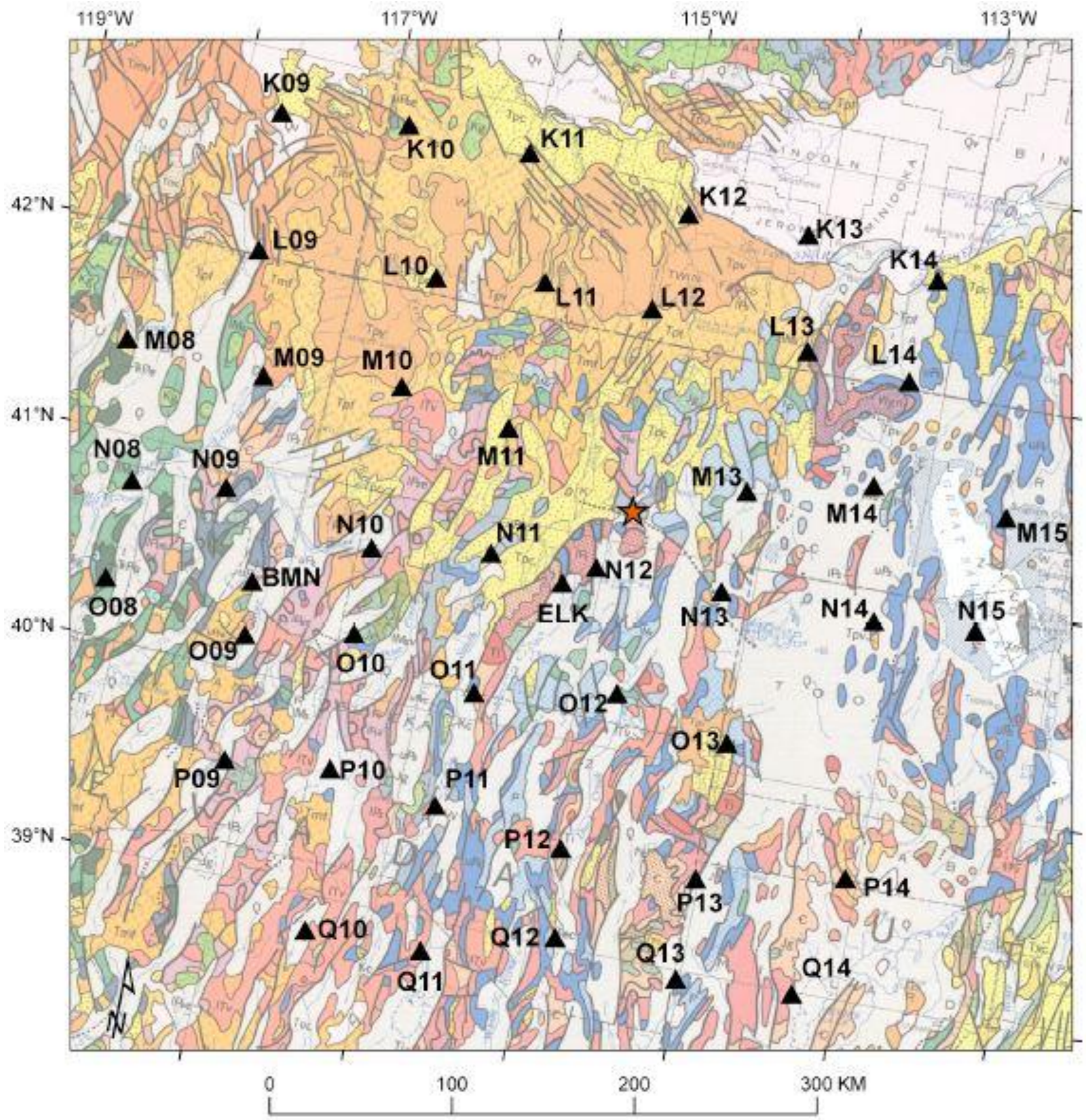

Figure 1. USArray and ANSS broadband stations (triangles) located within 300 km of the 2008 Wells, Nevada earthquake (star). The base map illustrates the geologic complexity of the seismic wave travel paths: light gray–Quaternary sediments; yellow–Tertiary continental deposits; orange–Tertiary volcanic rocks; green–Mesozoic volcanic and intrusive rocks; blue–Paleozoic volcanic and intrusive rocks. From Mendoza and Hartzell (2009).

Eight aftershocks with magnitudes between 3.8 and 4.6 M_W were used as EGFs (figure 2). These were projected perpendicularly onto the fault to select the appropriate aftershock record for each point source. The general approach was to use as many aftershocks as possible to allow a more complete representation of points across the fault. The focal mechanism of each point source is thus specified from the aftershock fault geometry. Source mechanisms calculated by Saint Louis University (www.eas.slu.edu/Earthquake_Center) for the eight aftershocks generally indicate normal faulting similar to that of the mainshock except for two events that show a significant strike-slip component. These differences in mechanism may indicate a spatial variation in faulting geometry across the fault or secondary post-seismic deformation away from the main fault plane. An additional EGF inversion of the observed data set was thus performed excluding the strike-slip events to examine the effects on the inferred source model. The results were very similar, indicating that it is not necessary to eliminate the two strike-slip events to effectively image the Wells earthquake rupture.

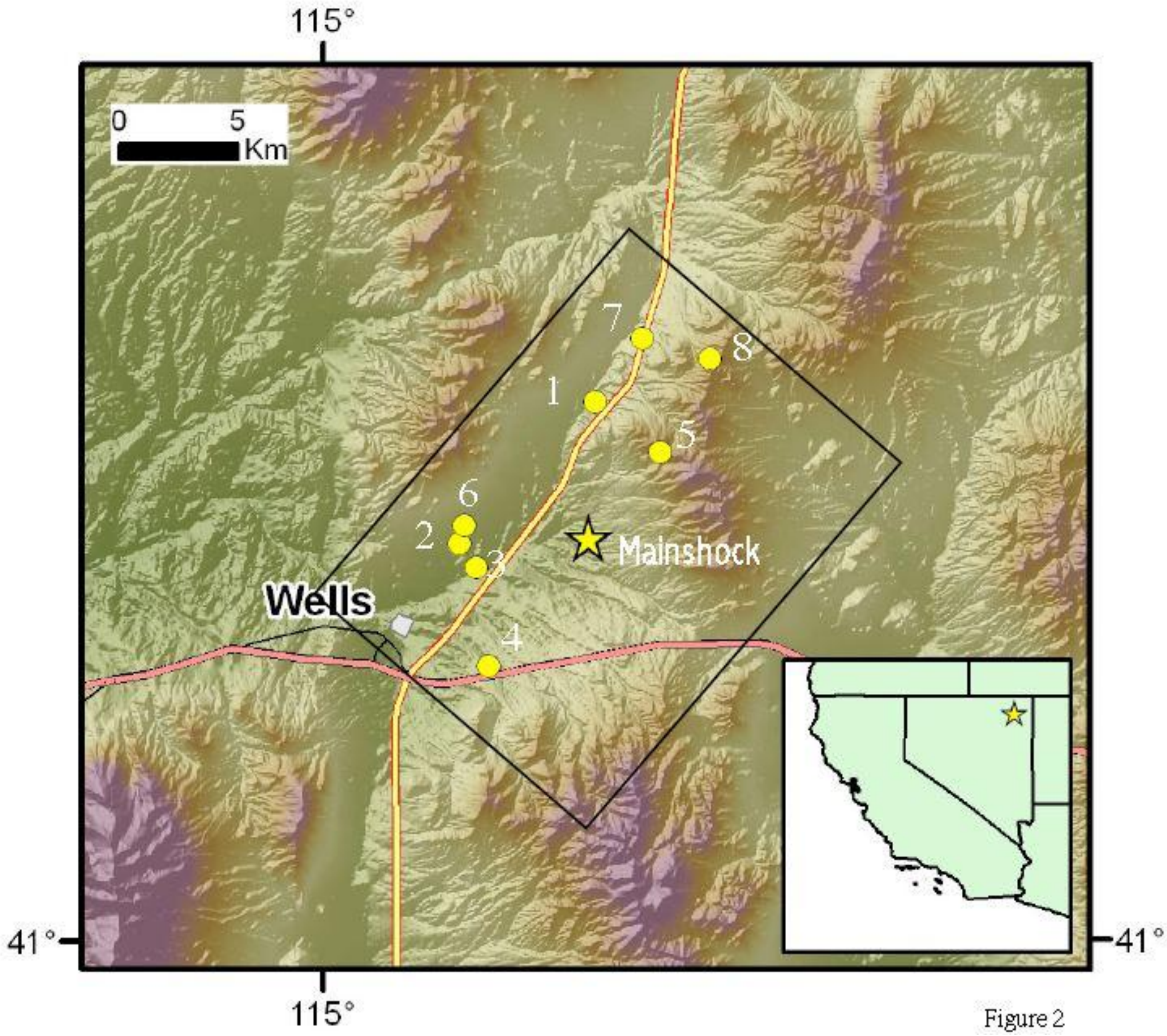

Figure 2. Location of the 2008 Wells earthquake epicenter (star) and the eight aftershocks (circles) used as EGFs by Mendoza and Hartzell (2009). The rectangle shows the surface projection of the fault plane used to model the mainshock.

RESULTS

Most of the coseismic slip inferred for the Wells earthquake is concentrated in a relatively compact 6-km by 4-km area with a maximum slip of 88 cm observed near the hypocenter (figure 3). Slip within this compact area occurs within 2 sec following rupture initiation, based on the assumed rupture velocity of 2.8 km/sec. Aftershock activity is mostly outside this principal rupture region, consistent with prior observations of aftershock distributions following large earthquakes (e.g., Mendoza and Hartzell, 1988). The stress drop in this compact region is estimated at 72 bars, and the total seismic moment is 6.2×10^{24}dyne-cm (M_W 5.8). This moment is slightly lower but comparable to other estimates, given the uncertainties in seismic-moment calculation.

Waveforms predicted by the inferred slip model fit the observed records quite well (figure 4) and account for the regional travel paths across the geologically complex Basin and Range province. The results of the study suggest that the use of EGFs in regional finite-fault source studies may ultimately provide a more accurate estimate of the coseismic rupture history compared to source models based on numerically calculated Green's functions. Thus the approach would be useful for studying smaller-sized earthquakes that remain unrecorded at a global scale and also earthquakes recorded at few strong-motion sites.

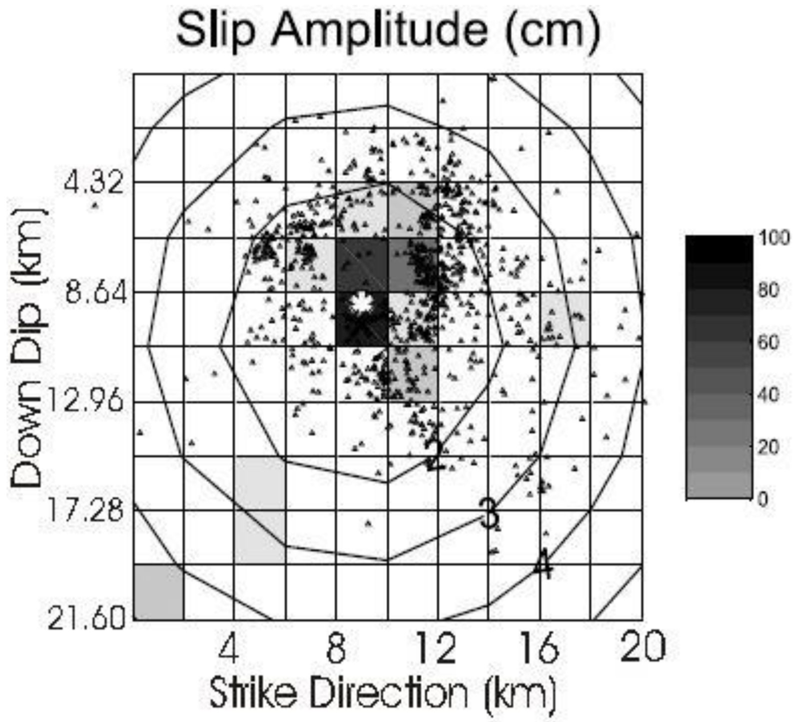

Figure 3. Coseismic slip inferred for the 2008 Wells, Nevada earthquake by Mendoza and Hartzell (2009) from the EGF analysis. The fault plane corresponds to the rectangle from figure 2 as viewed from above in a direction perpendicular to the fault. Thus, the left side of fault is to the SW and the right side is to the NE. Contours indicate the rupture time in seconds for a pulse originating at the hypocenter (asterisk) and propagating at a velocity of 2.8 km/sec across the fault. Small triangles show aftershock hypocenters projected onto the earthquake fault.

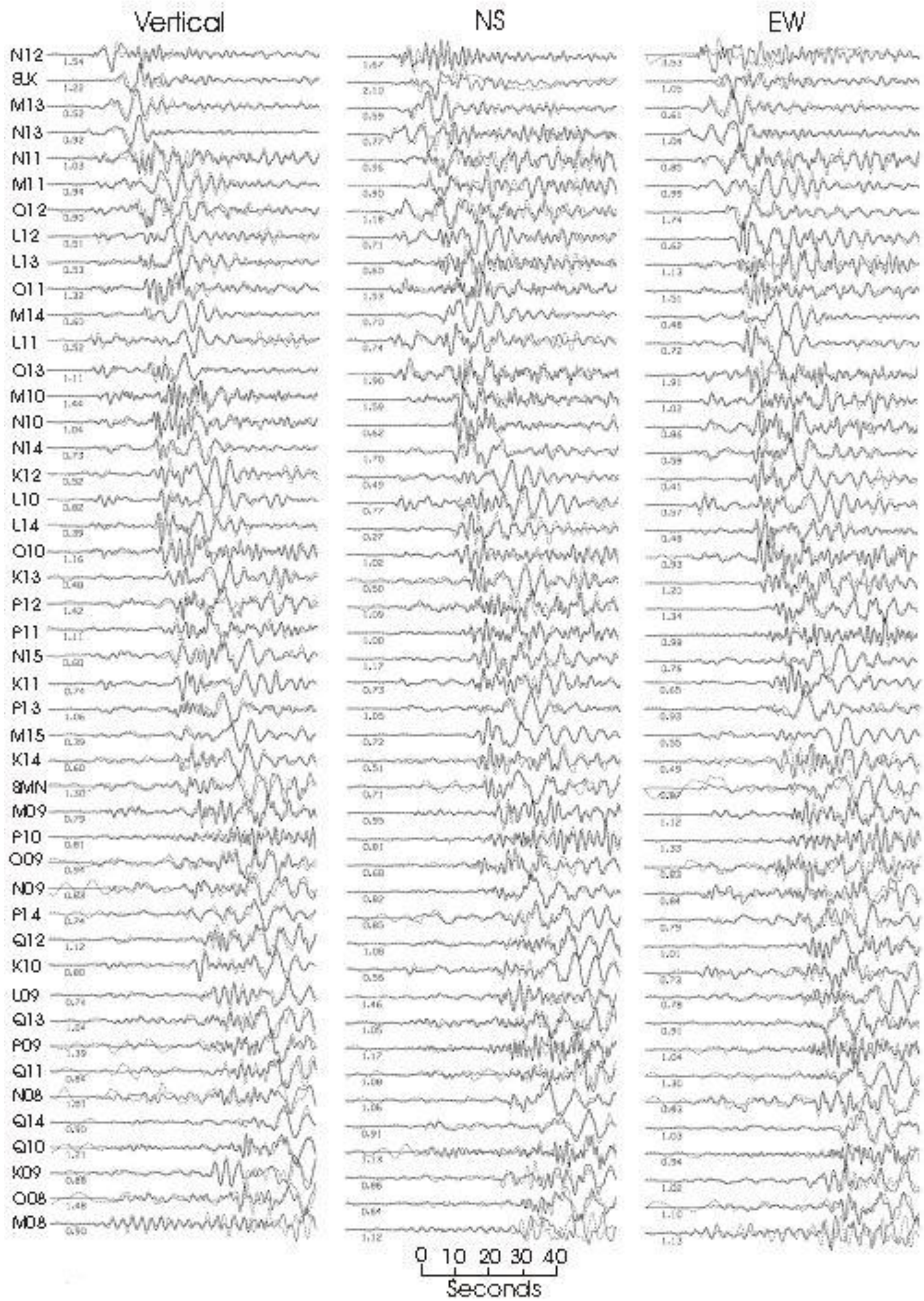

Figure 4. Observed (solid) and predicted (dotted) vertical, north-south (NS), and east-west (EW) bandpass-filtered velocity records for the source model inferred by Mendoza and Hartzell (2009) for the 2008 Wells earthquake. Records are shown in order of increasing epicentral distance from top to bottom with numbers indicating the ratio of predicted-to-observed amplitudes.

REFERENCES

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