Lg wave attenuation in the CEUS:

Gulf Coastal Plain Region

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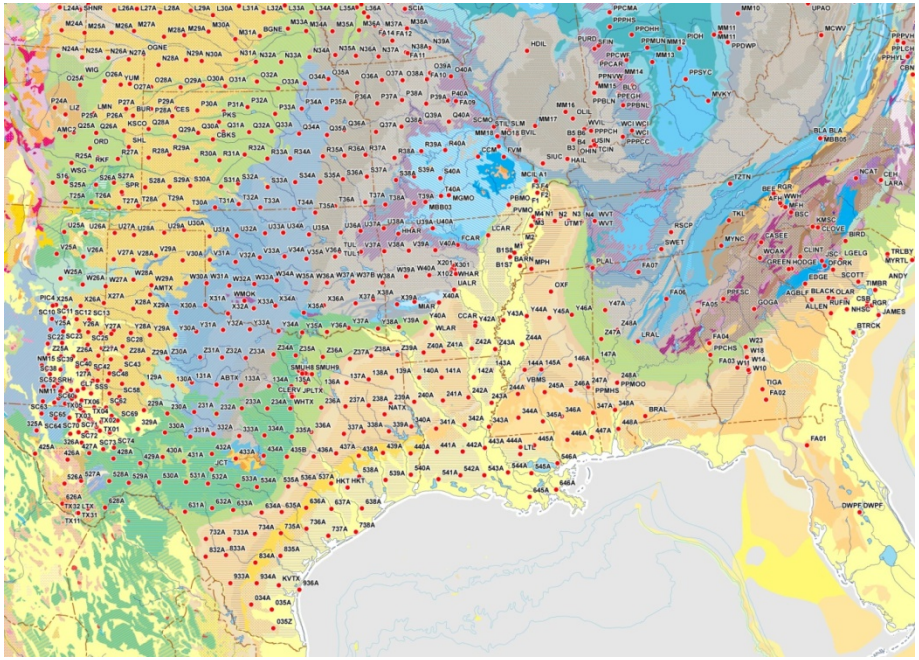
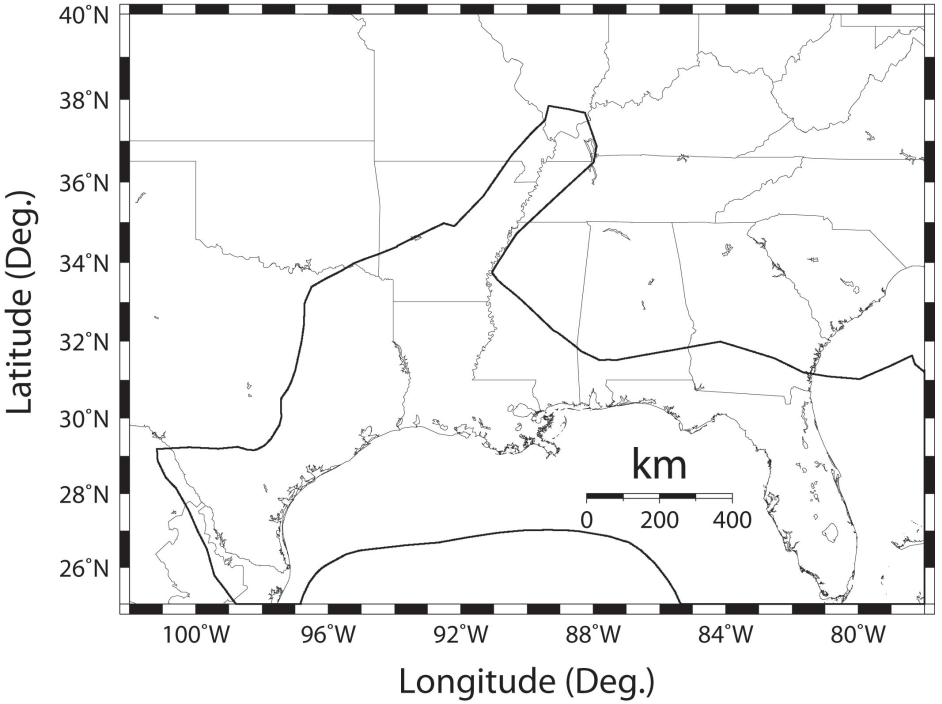
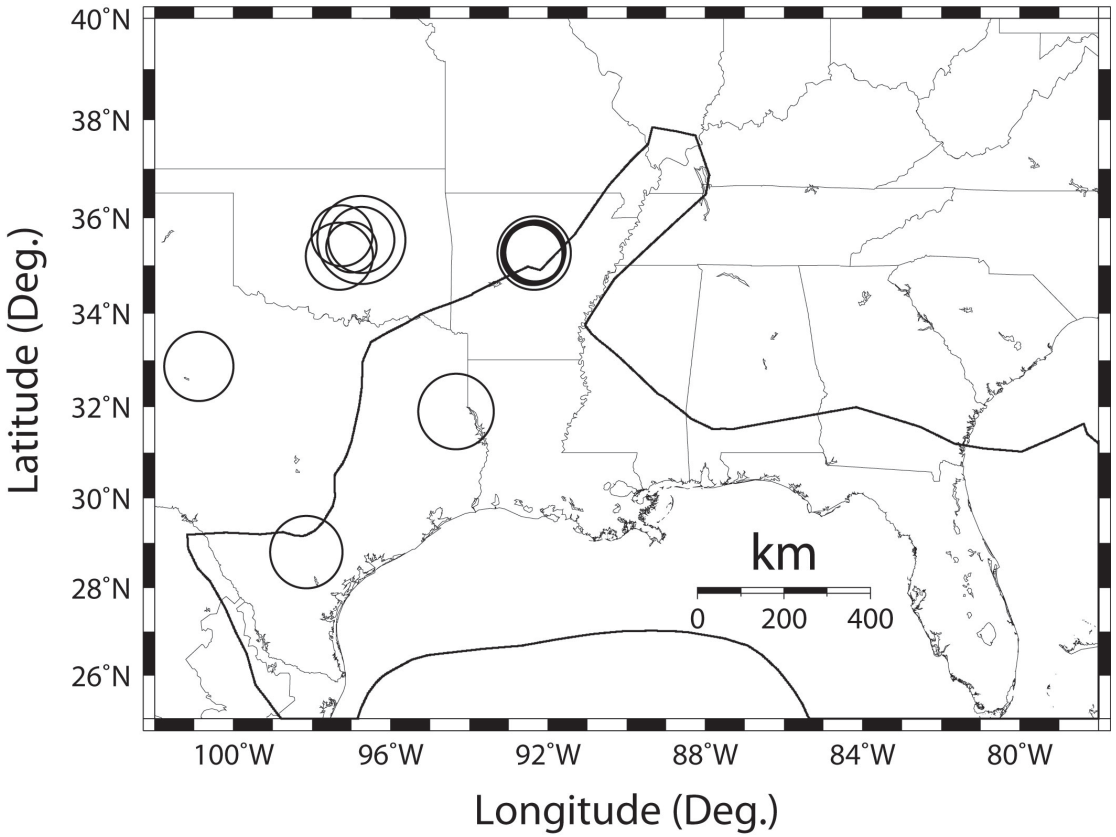


Geologic map showing the locations of EARTHSCOPE Transportable Array stations installed as of April, 2011, as well as other regional broadband stations.



Gulf Coast region used for attenuation study.



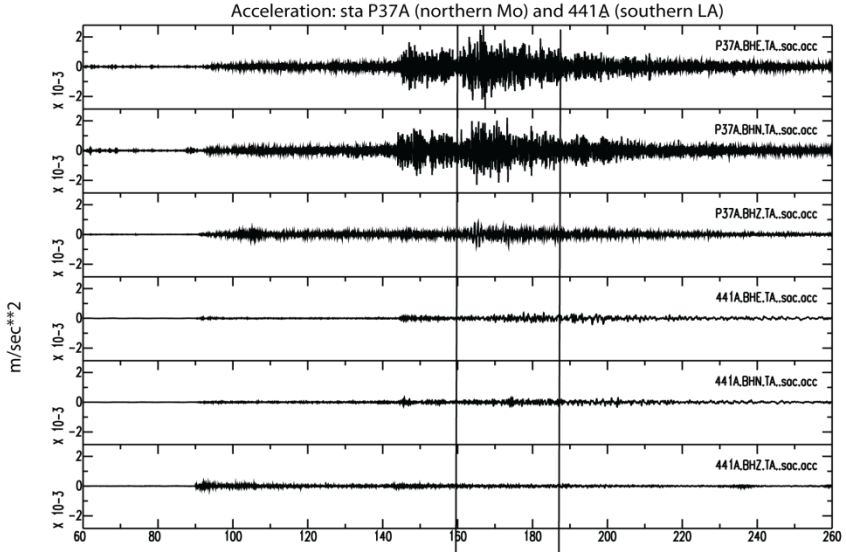
Circles show epicenters of 16 earthquakes listed in Table 1.

Table 1

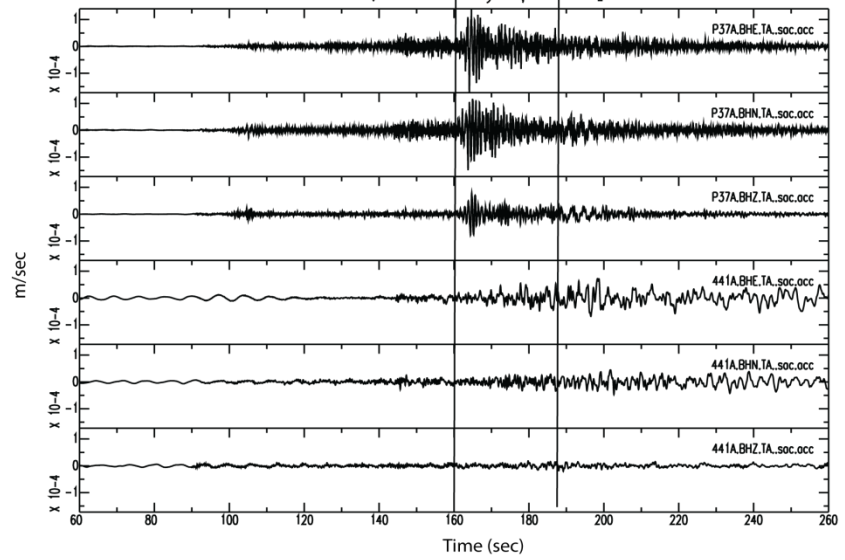
Date	Lat.	Long.	Moment Magnitude
10-13-2010	35.202	-97.309	4.33
10-15-2010	35.276	-92.322	3.80
11-20-2010	35.316	-92.317	3.90
11-24-2010	35.627	-97.246	3.90
12-27-2010	35.540	-96.750	4.15
12-12-2010	35.392	-96.995	3.20
02-17-2011	35.276	-92.361	3.80
02-18-2011	35.257	-92.370	3.90
02-18-2011	35.271	-92.377	4.10
02-28-2011	35.265	-93.340	4.65
04-07-2011	35.350	-92.373	3.73
04-08-2011	35.261	-92.362	3.90
11-06-2011	35.537	-96.747	5.60
09-11-2011	32.874	-100.876	4.40
10-20-2011	28.806	-98.147	4.60
05-17-2012	31.902	-94.332	4.83

Central Arkansas Earthquake 2/28/2011 M 4.7

Acceleration: sta P37A (northern Mo) and 441A (southern LA)



Velocity

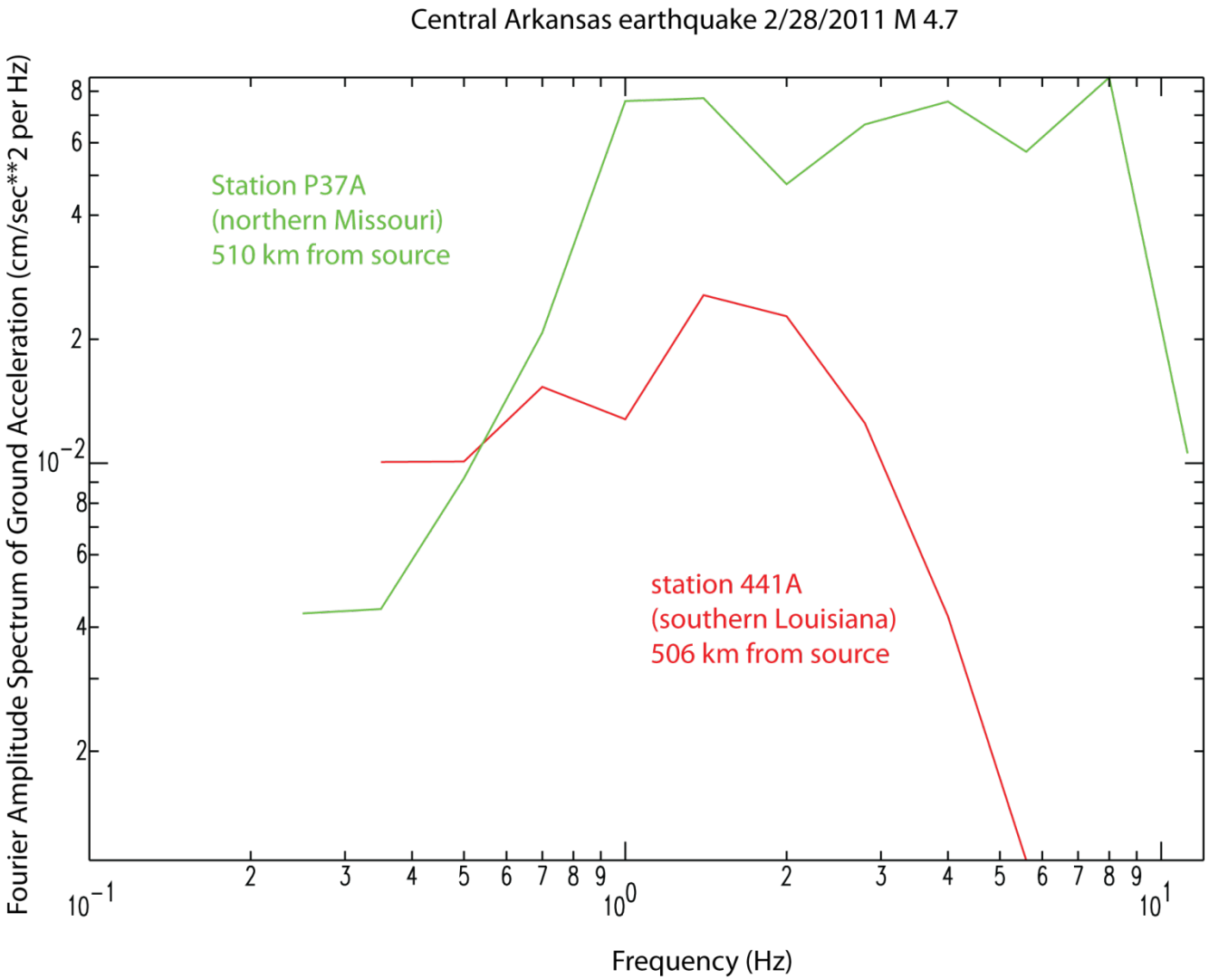


TLg TLg+Td

TLg = origin time + r / 3.53

Td = 8.71 + 0.026 r

Td is the time at which the integral of acceleration squared between time TLg and TLg + 100 seconds reaches 70% of the maximum value.



Lg signal amplitudes exceed noise amplitudes in equal-length time windows (Td) prior to the predicted P or Pn arrival time BY AT LEAST A FACTOR OF 5.

Regression Model

$$Ln\left[\frac{A_{ij}(f)}{S_i(f)G(r_{ij})}\right] = R_j(f) - \frac{\pi r_{ij} f}{QV}$$

$A_{ij}(f)$ = Fourier acceleration amplitude (geometric mean of the two horizontal components),
$S_i(f)$ = Earthquake source amplitude spectrum,
$G(r_{ij})$ = Geometrical spreading (independent of frequency f),
$R_j(f)$ = Receiver (Site) amplitude term,
r_{ij} = epicentral distance, from ith earthquake to the jth receiver station.
V = Lg velocity (3.53 km/s).

Geometrical Spreading Model 1

$$G(r) = r^{-1.3},\ r \leq 60\ km$$

$$G(r) = 60^{-1.3}, 60 \leq r \leq 120\ km$$

$$G(r) = 60^{-1.3}\left(\frac{r}{120}\right)^{-0.5}, r > 120\ km$$

Geometrical Spreading Model 2

$$G(r) = r^{-1.0}, \qquad r \leq 60\ km$$

$$G(r) = 60^{-1.0}, \qquad 60 \leq r \leq 120\ km$$

$$G(r) = 60^{-1.0}\left(\frac{r}{120}\right)^{-0.5}, r > 120\ km$$

$$R_j(f) = Ln\{A_j \exp(-\pi k_j f)\} = lnA_j - \pi k_j f$$

The receiver terms R_j for the jth station at each of 12 frequencies between 0.25 and 12 Hz can be used to estimate A_j and k_j by linear regression.

The zero frequency intercept term Ln(Aj) represents a frequency-independent "Site Factor" for each receiver.

$$S_i(f) = \frac{M_{0i}(2\pi f)^2}{1 + \left(\frac{f}{f_c}\right)^2} \left(\frac{1}{4\pi\rho\beta^3}\right)$$

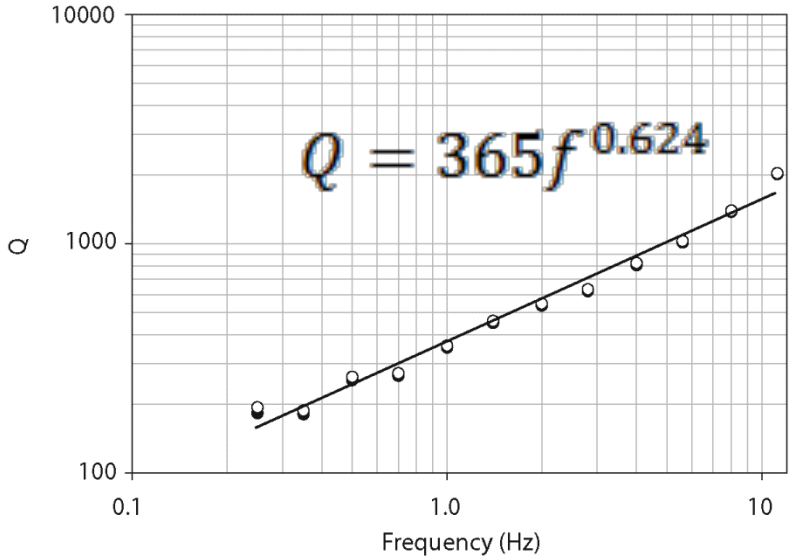
The source terms S_i (for a unit distance) do not include the radiation pattern or a free surface effect. Hence, a factor of approximately 2, due to the free free surface, will be absorbed in the site factor A_j. The radiation pattern term will contribute to scatter in the site factors.

Estimates of Q: 10 MPa stress drop

	Geo. spreading model 1		Geo. spreading model 2	
Frequency (Hz)	Q	s	Q	s
0.25	182	37	179	37
0.35	180	17	179	16
0.50	254	22	252	23
0.70	265	17	265	16
1.00	352	21	350	22
1.40	451	25	449	25
2.00	537	25	535	25
2.80	620	25	617	25
4.00	806	32	805	32
5.60	1013	40	1013	40
8.00	1377	62	1374	61
11.2	2009	141	2012	142

The estimates of Q are not sensitive to the choice of geometrical spreading

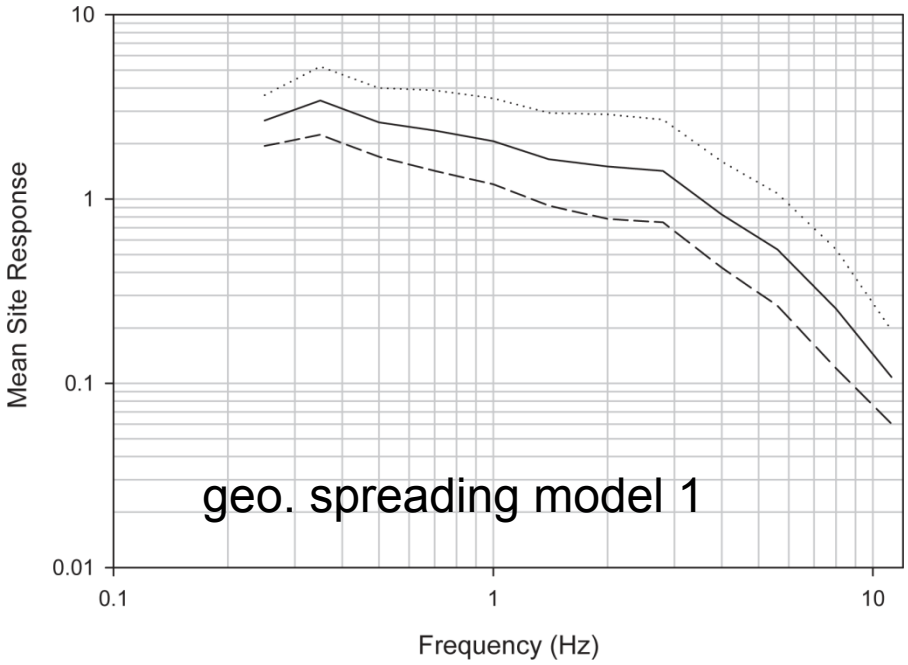
Q for the Basement in the Gulf Coast Region

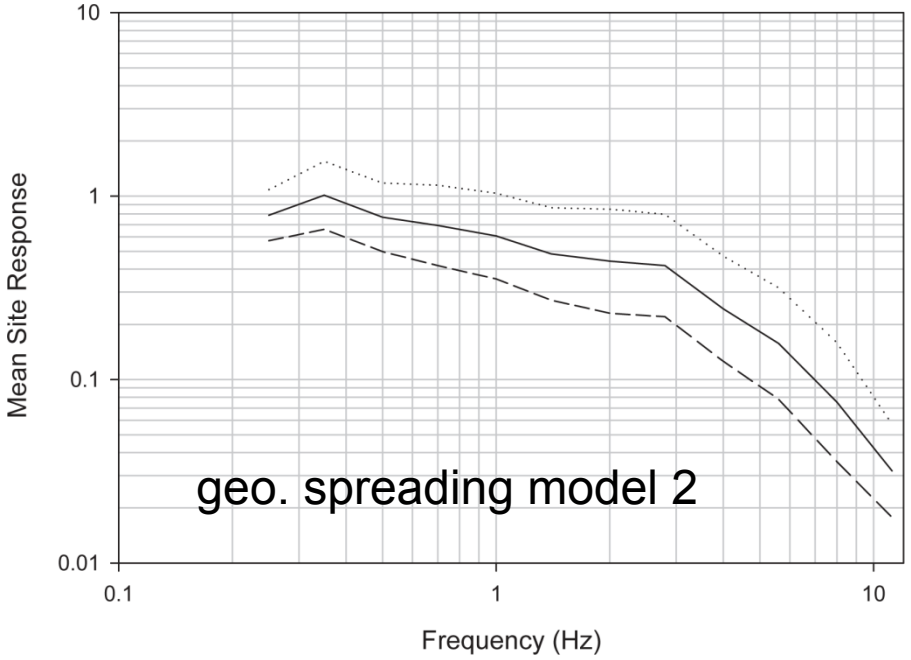


Open Circles: 10 MPa stress drop
Filled Circles: 5 MPa stress drop

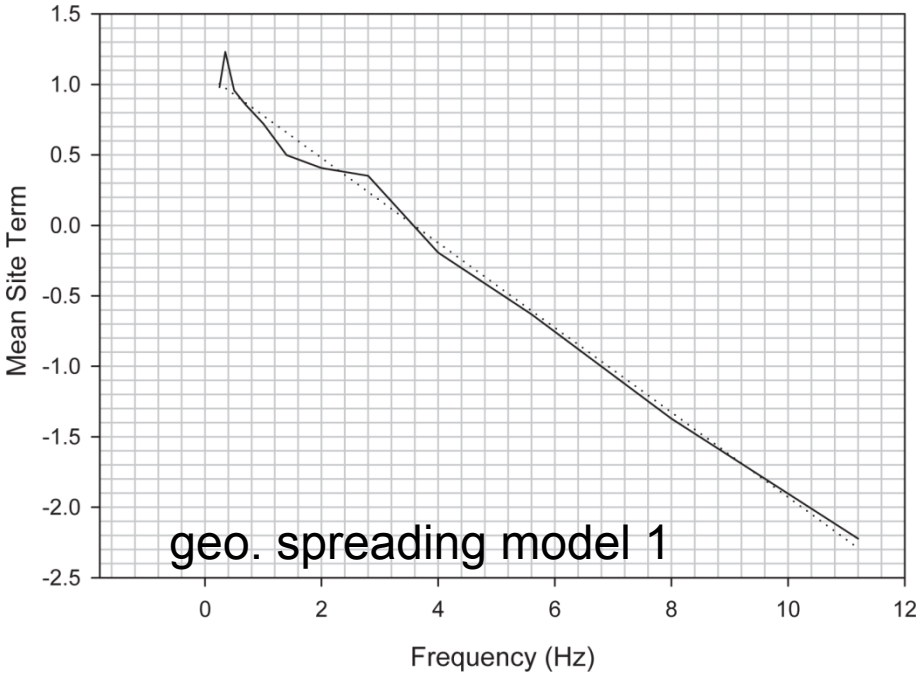
The estimates of Q are not sensitive to the assumed stress drop

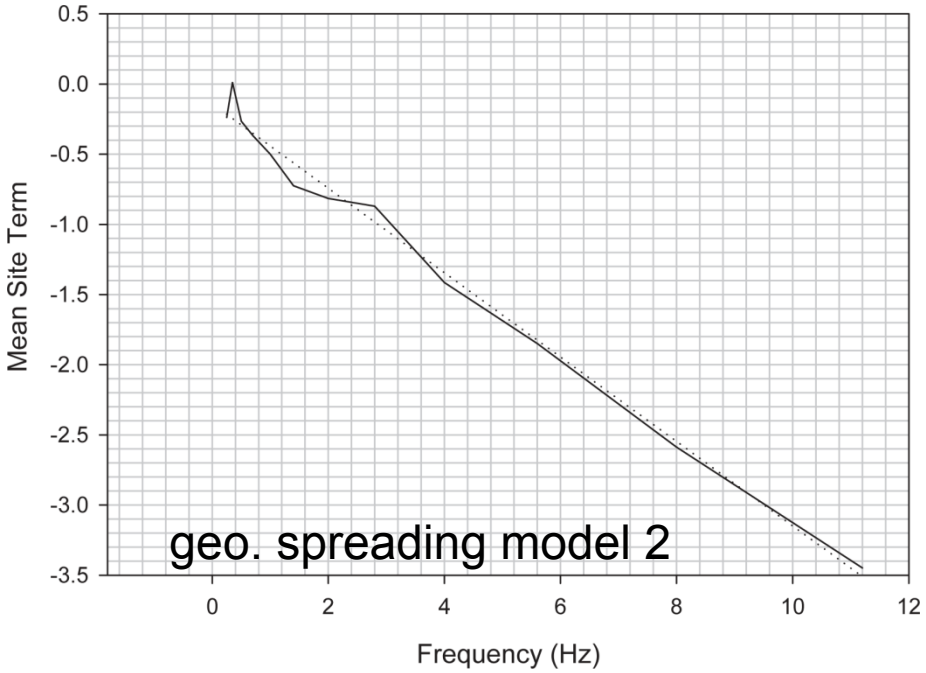
Mean +/- 1 Standard Deviation Site Response For Stations South of 33N Lat.





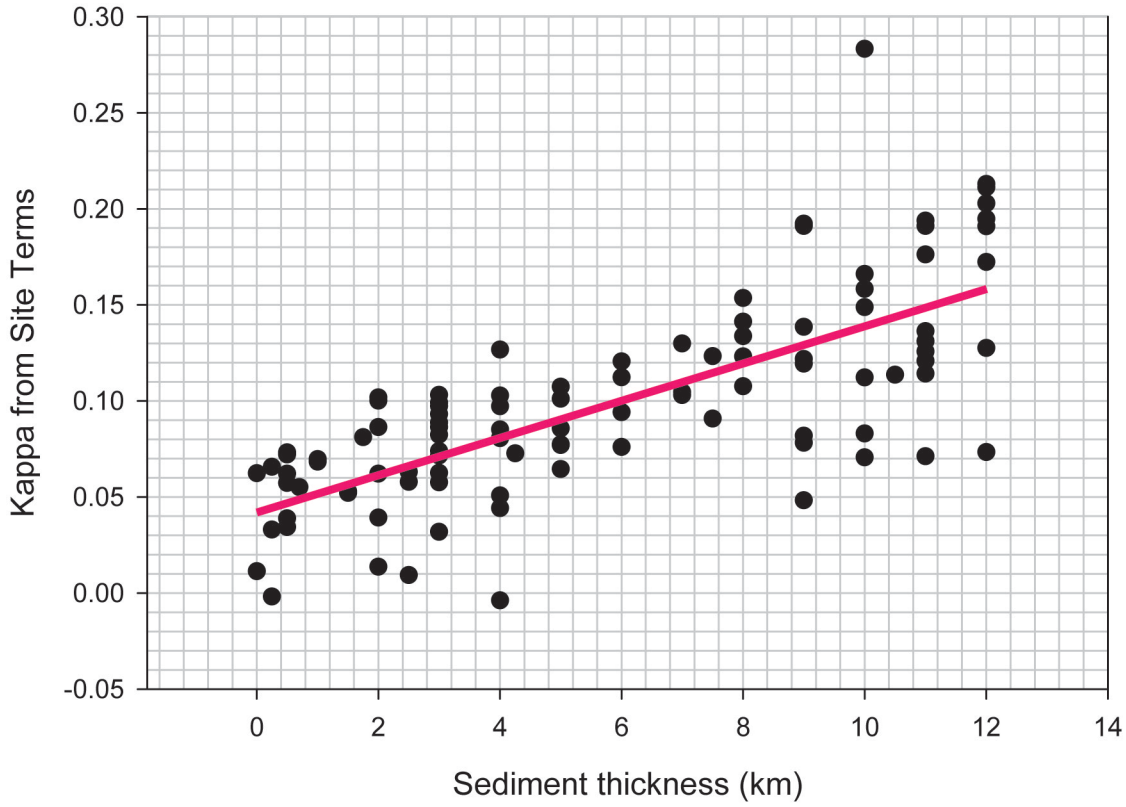
The amplitudes of the site response terms are sensitive to the assumed model for geometrical spreading. But the shape of the average site response spectrum not. This means that average Kappa for sites in the Gulf Region can be reliably estimated from the Earthscope TA data.



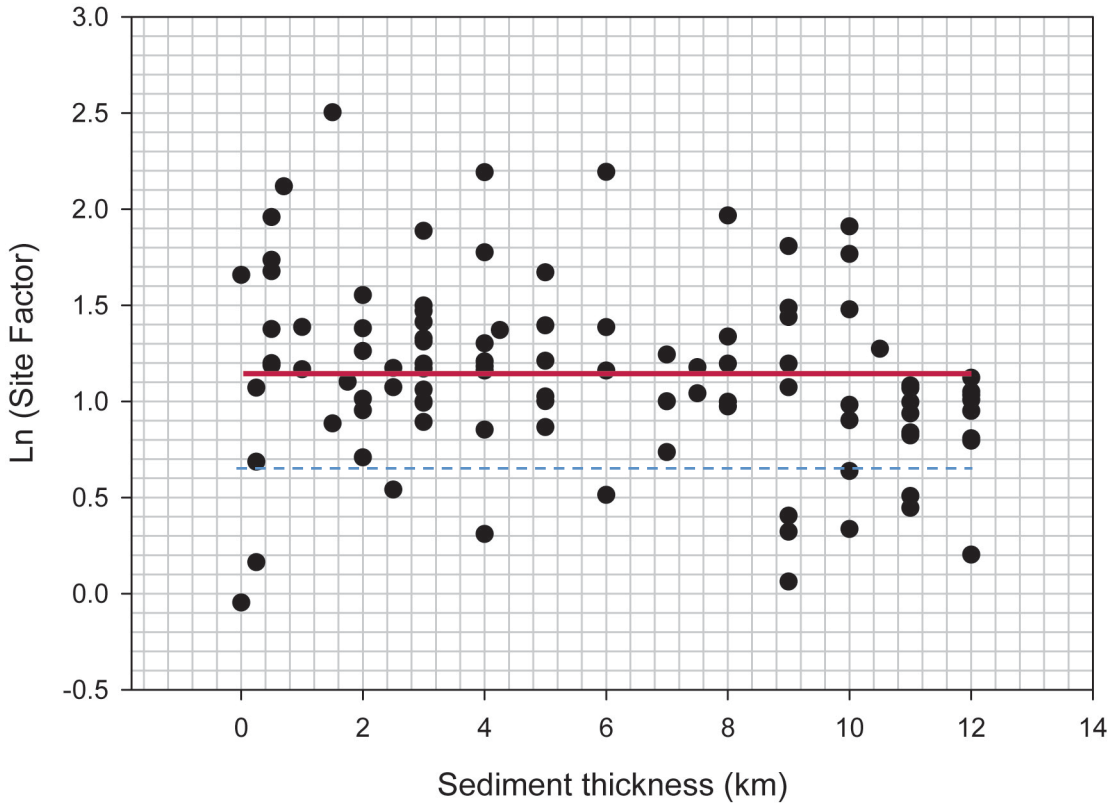


The slope of the Site Term versus frequency function gives an estimate of Kappa (K_o) For the average site condition in the Gulf Region south of Latitude 33N, K_o = 0.096 seconds.

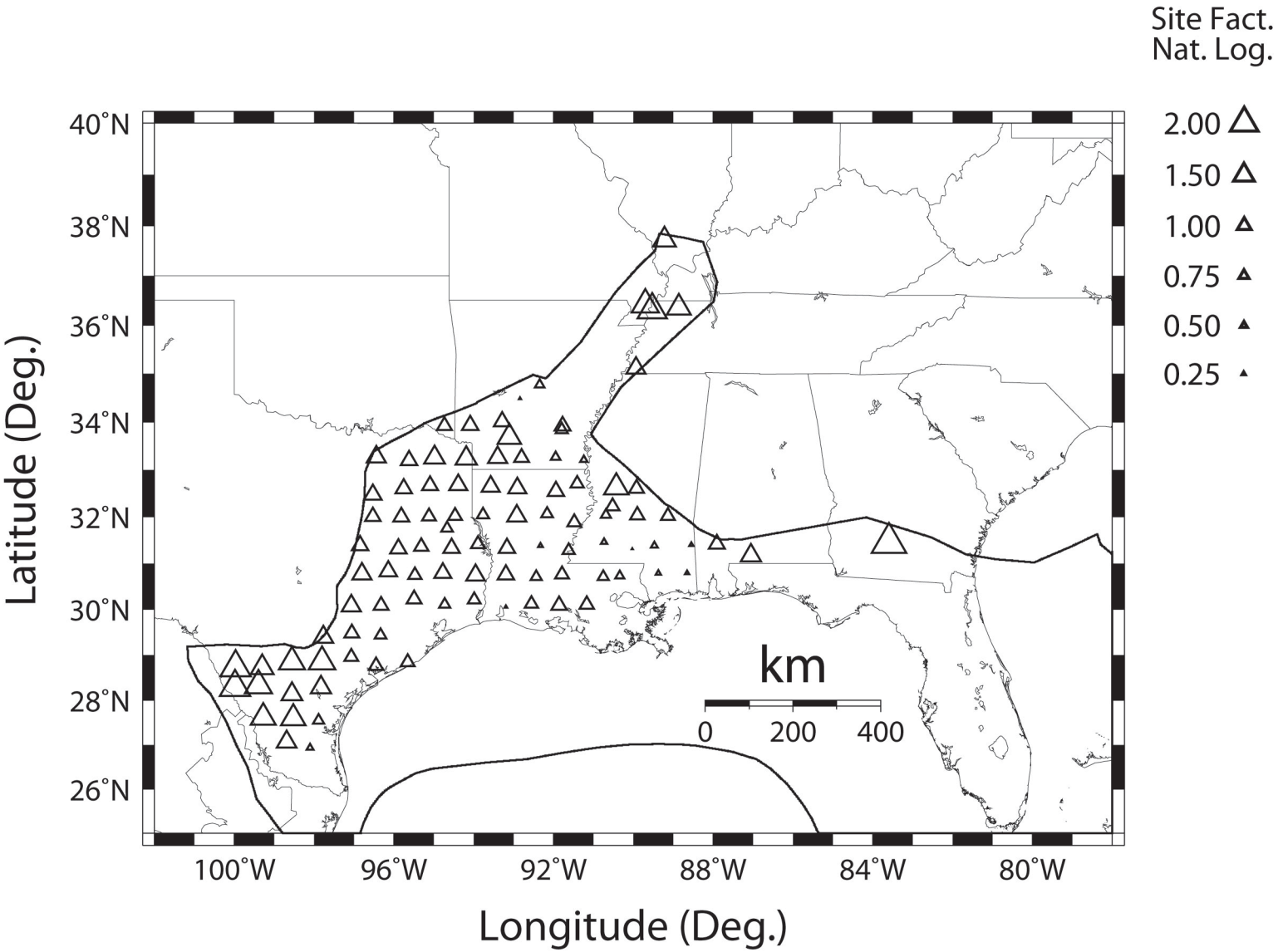
$K_o = 0.043 + 0.0097$ (sediment thickness, km)

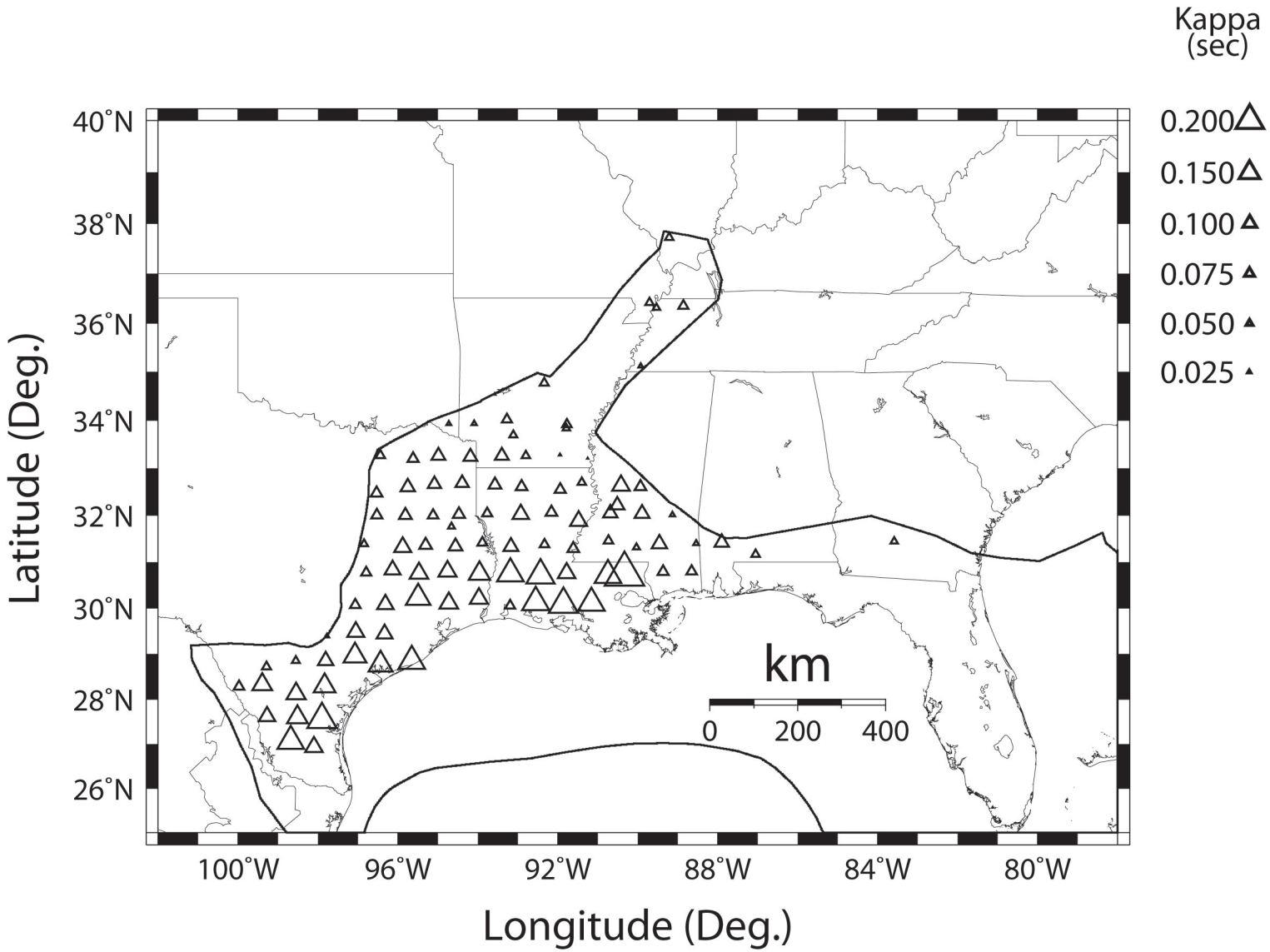


mean: 1.14 standard deviation: 0.47



Factor of 2
(Free Surface)


Site Fact.
Nat. Log.
2.00
1.50
1.00
0.75
0.50
0.25
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
Latitude (Deg.)
km
0
200
400
100°W
96°W
92°W
88°W
84°W
80°W
Longitude (Deg.)


Kappa
(sec)
0.200
0.150
0.100
0.075
0.050
0.025
40°N
38°N
36°N
34°N
32°N
30°N
28°N
26°N
Latitude (Deg.)
km
0
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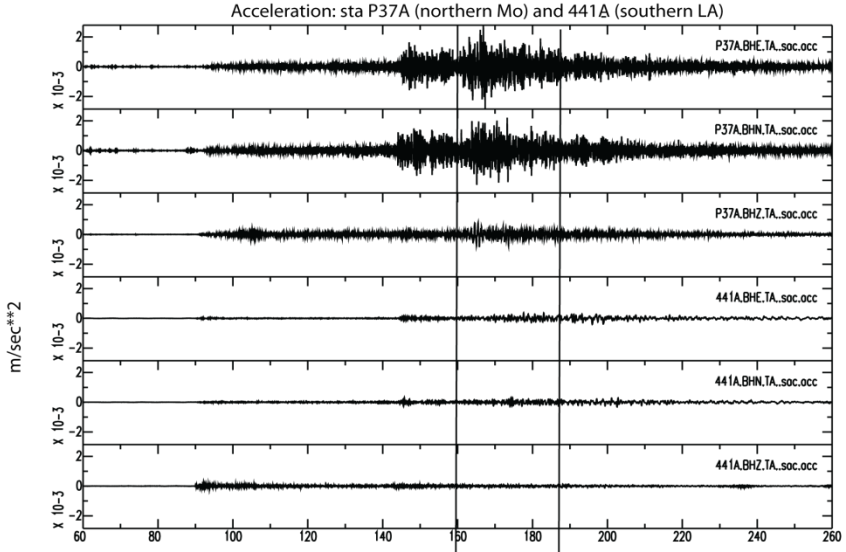
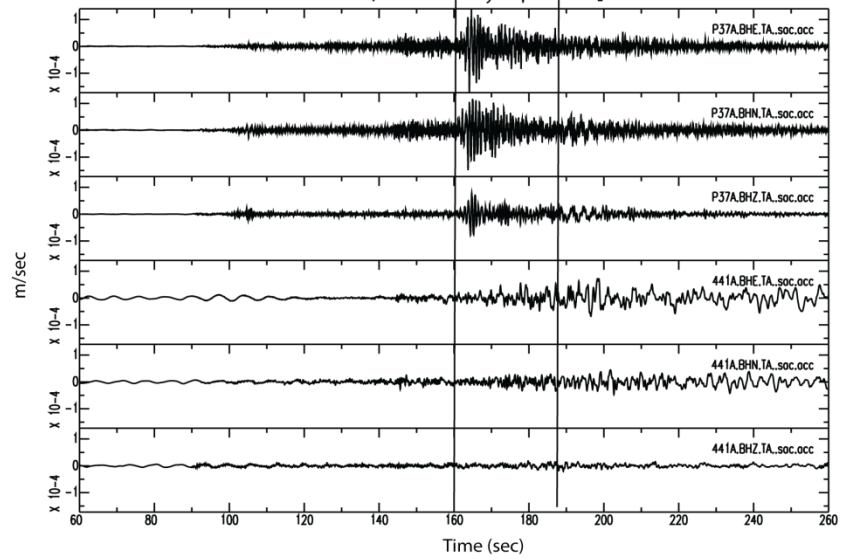


Velocity



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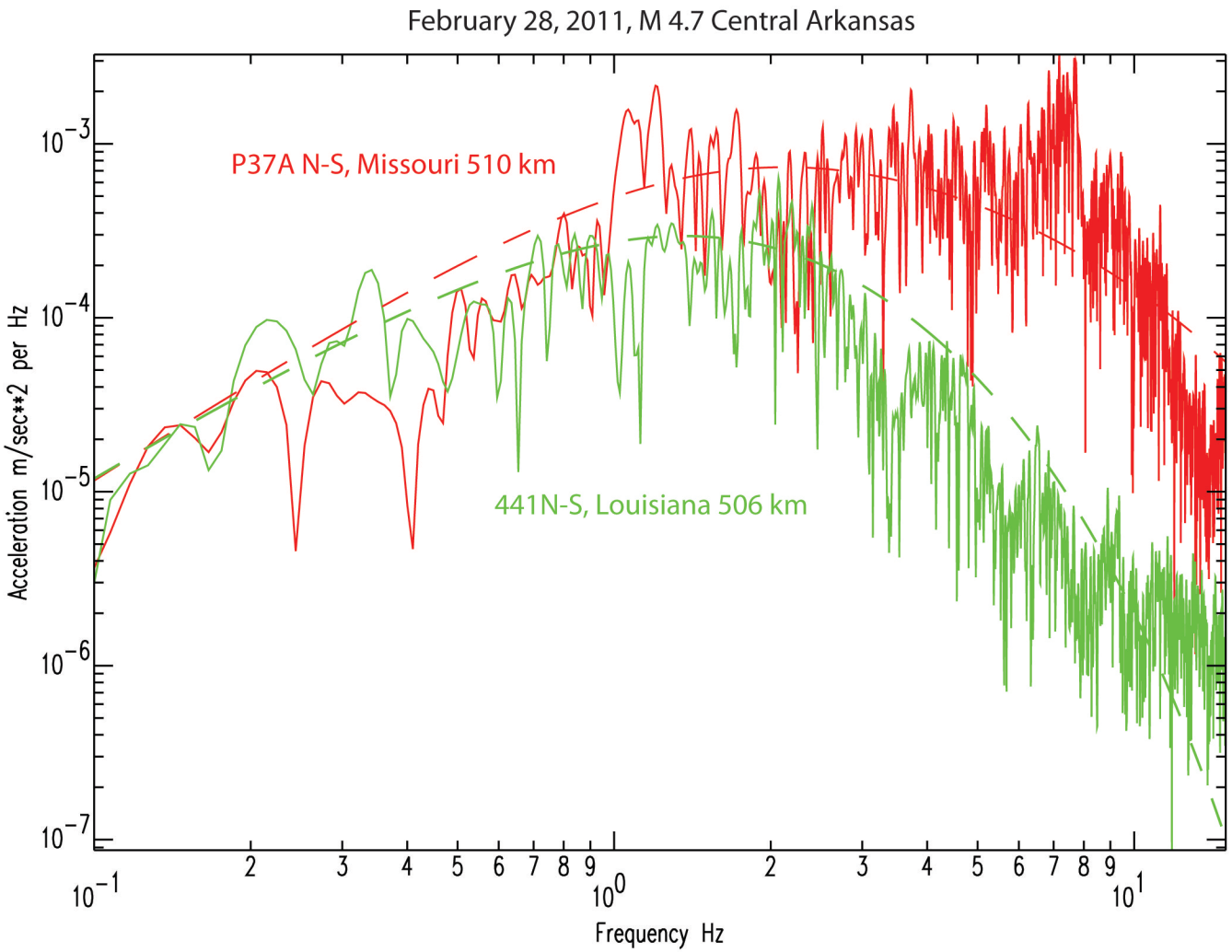

Green Dashed Line: Predicted Spectrum, using Gulf Q and Gulf Kappa models, 100 bars, spreading model 1

Red Dashed line: Predicted Spectrum, using Erickson et al. (2004) Cent. U.S. Q model, 100 bars, spreading model 1

Conclusions

Lg attenuation in the Gulf Coastal Plain is strongly attenuated from sources to the North.

The attenuation shows a strong correlation with the thickness of the sedimentary section.

Distance dependent anelastic attenuation is modeled using a regional value of $Q = 365\ f^{0.624}$

The majority of attenuation observed is due to either Lg blockage, and/or attenuation by thick sediments.

An approach involving a frequency independent site factor and a frequency-dependent attenuation operator using site specific Kappa (K_o) that increases with sediment thickness appears to be a viable approach to developing models for the prediction of Lg amplitudes.