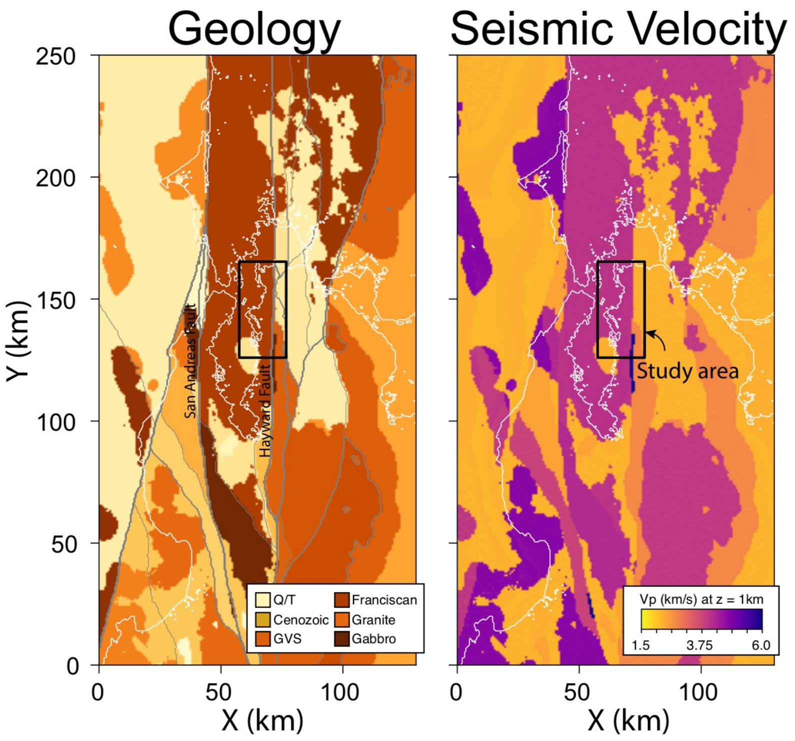
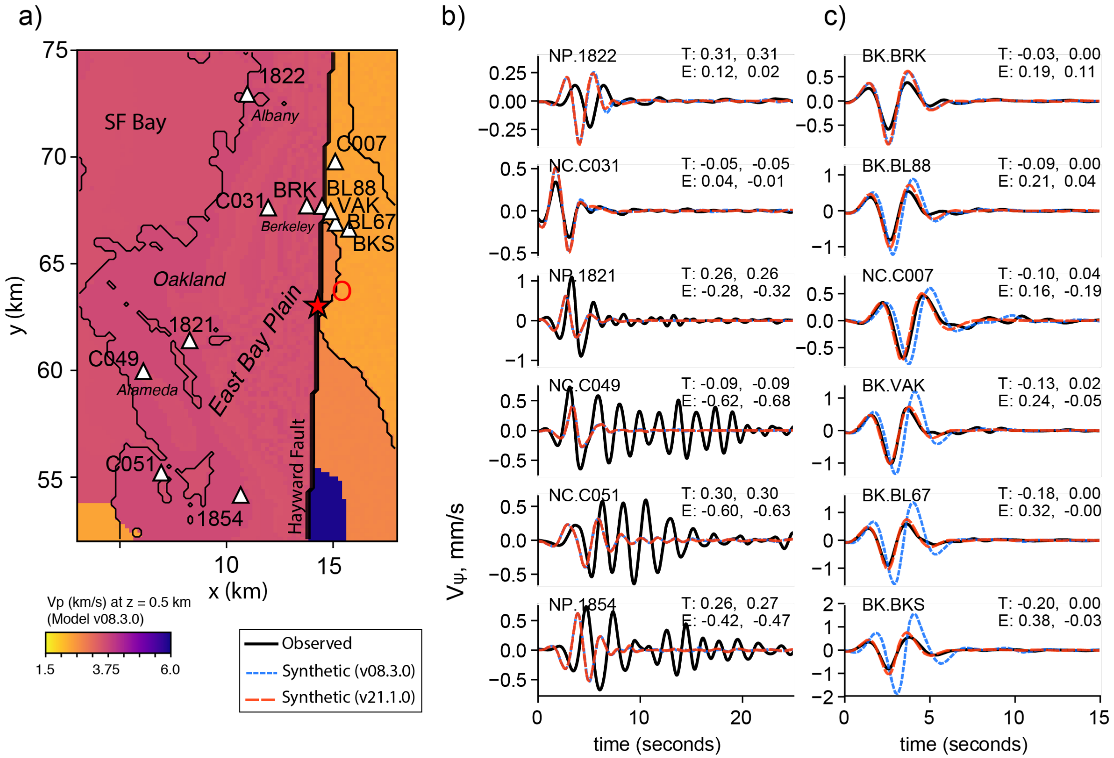
Simulation of Long Duration Shaking in Oakland and Alameda, CA

Evan Hirakawa, Brad Aagaard, USGS

SF Bay Velocity Model Workshop, May 10, 2021

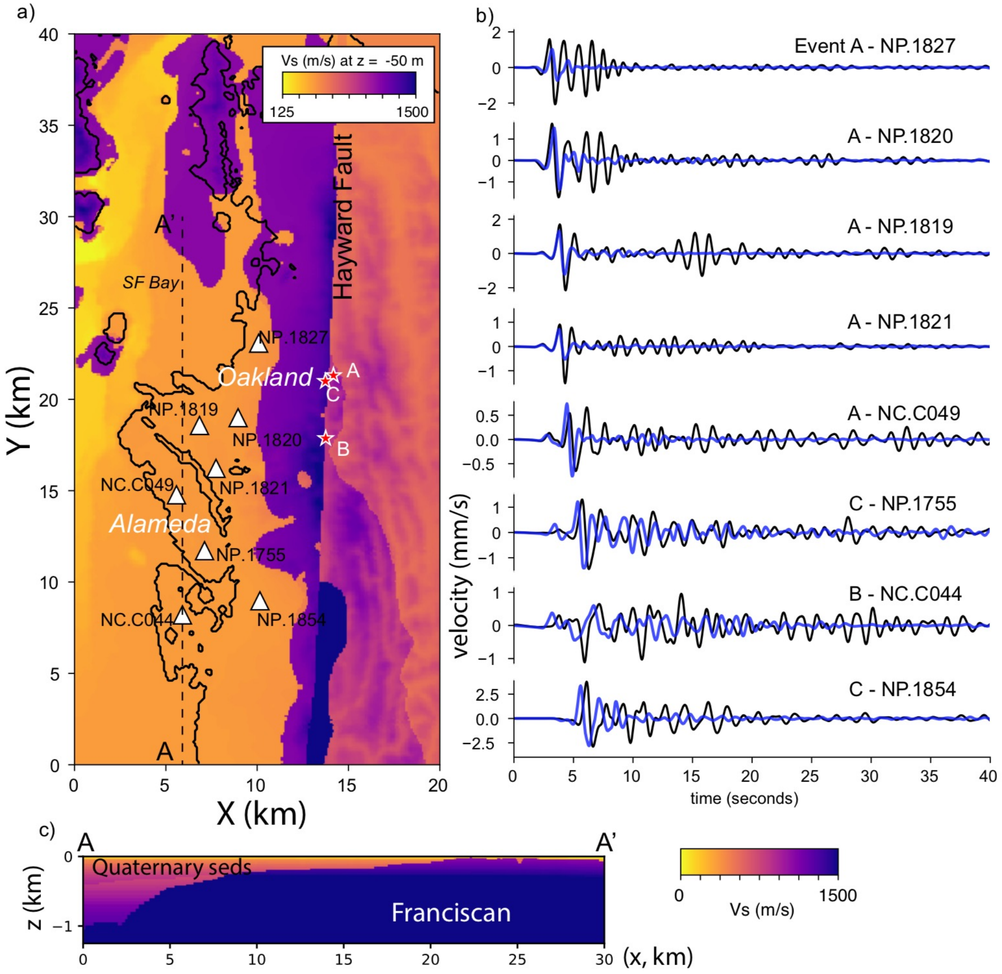
… in previous work, we noticed long shaking in the East Bay Plain that is not reproduced with the USGS SF Bay region 3D seismic velocity model





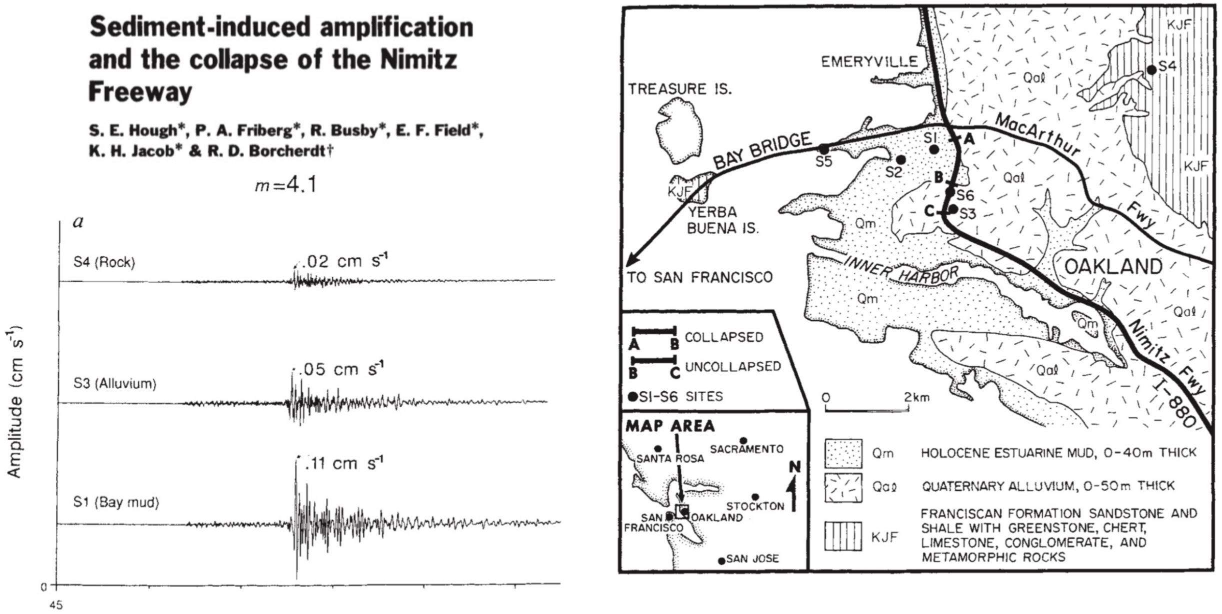
Hirakawa and Aagaard, in review, 2021

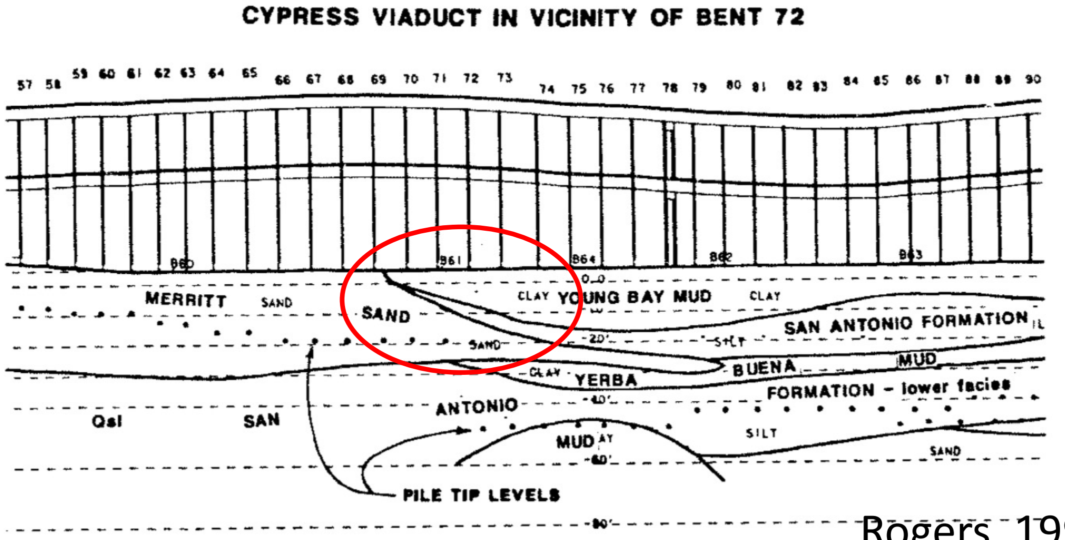
What is the cause of long duration shaking?



From SW4 simulations, black is observed, blue is simulations

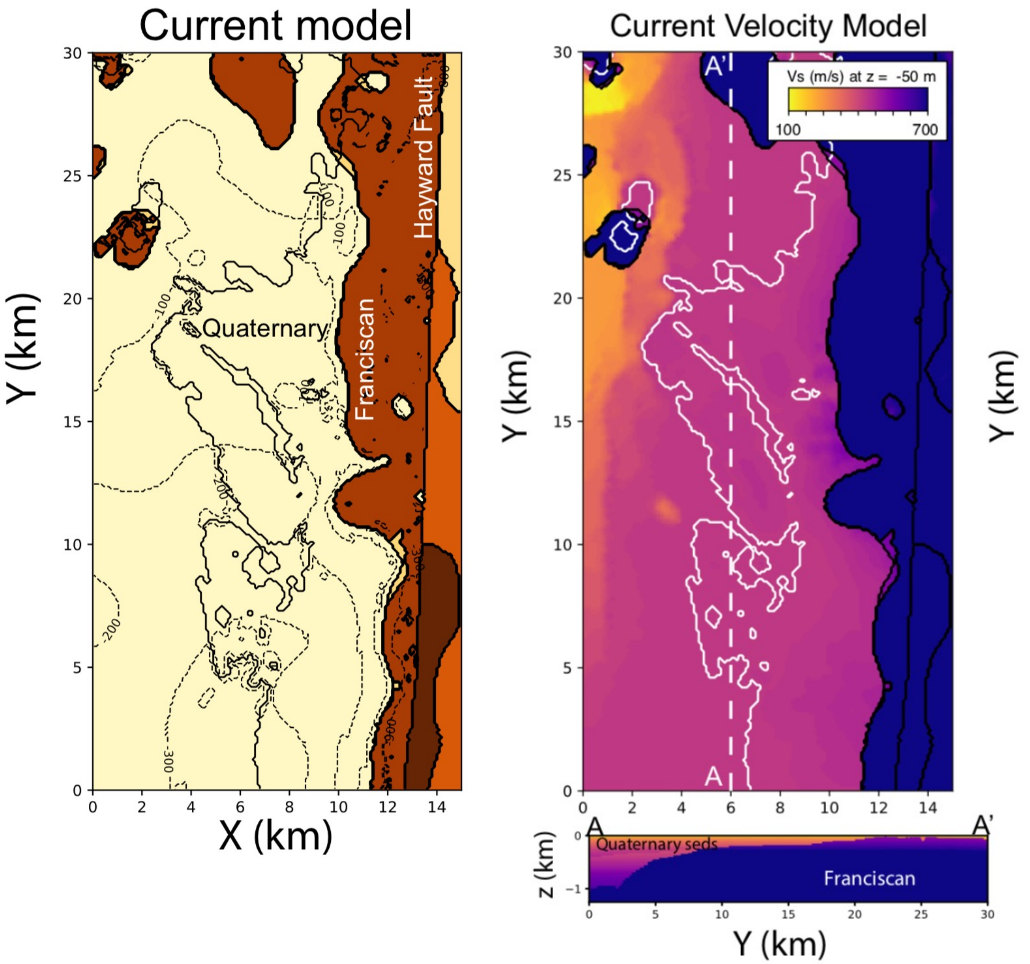
Historic shaking in this area: 1989 Mw 6.9 Loma Prieta Earthquake





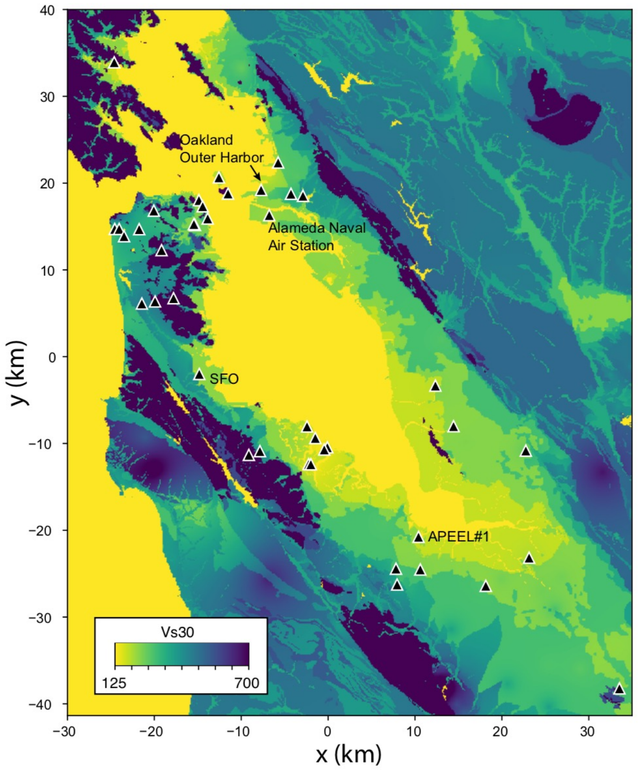
Rogers, 1991

USGS SF Bay region velocity model does not currently distinguish Bay Mud from other Quaternary sediments



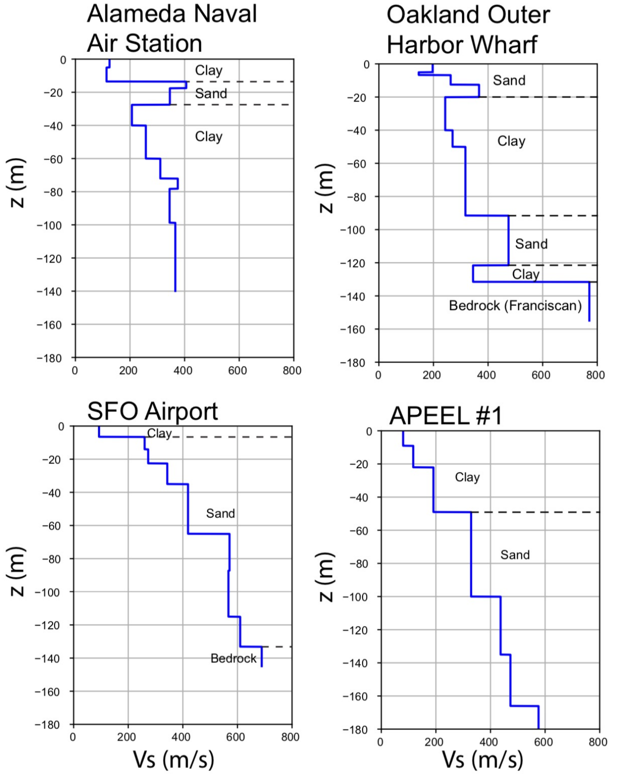
Bringing in more outside data…

1. Vs30 map with geologic and topographic constraints



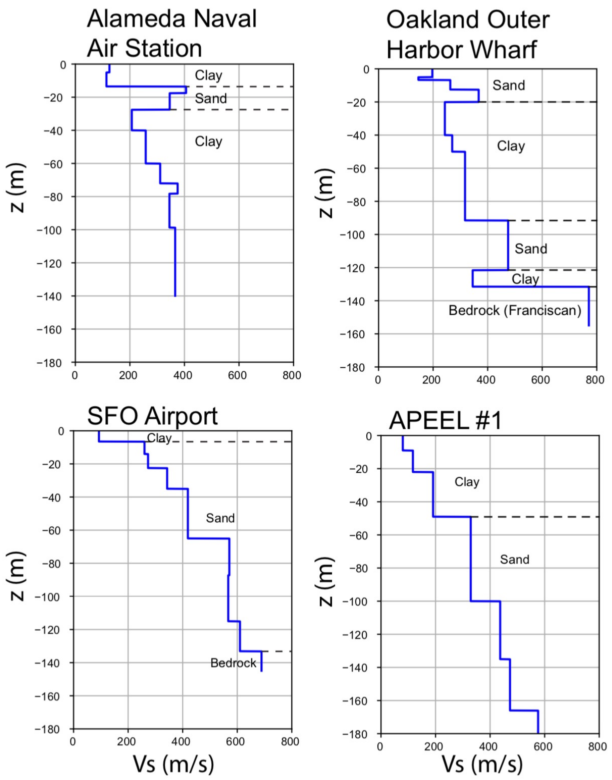
Thompson, 2018

2. Downhole geologic logs and 1D seismic velocity models

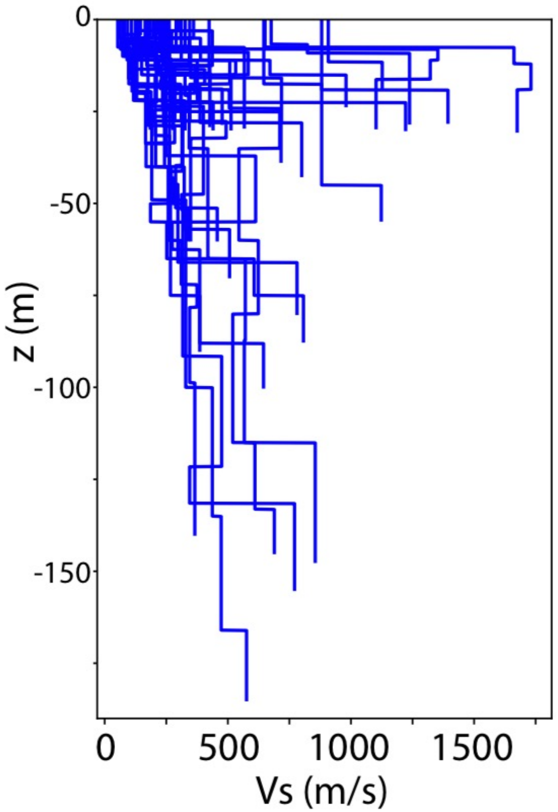


Gibbs et al., 1992;
Boore, 2003

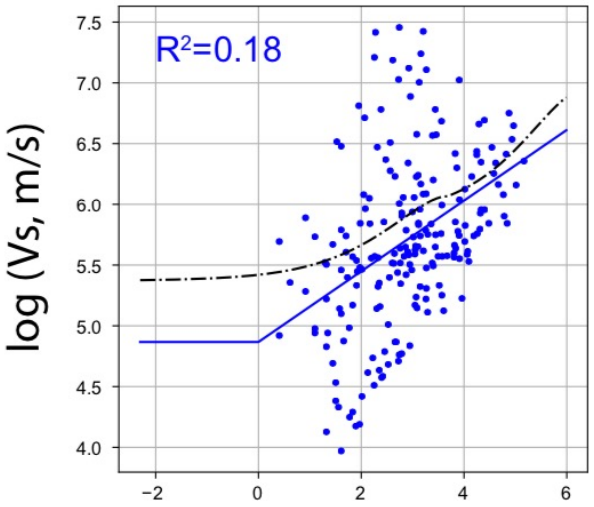
Fitting new rules with Boore (2003) 1D velocity models



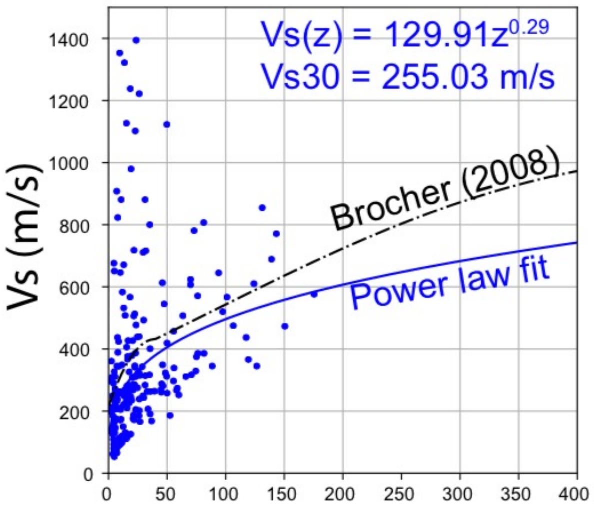
Gibbs et al, 1992



Compilation of all profiles in Central Bay Block, Boore 2003

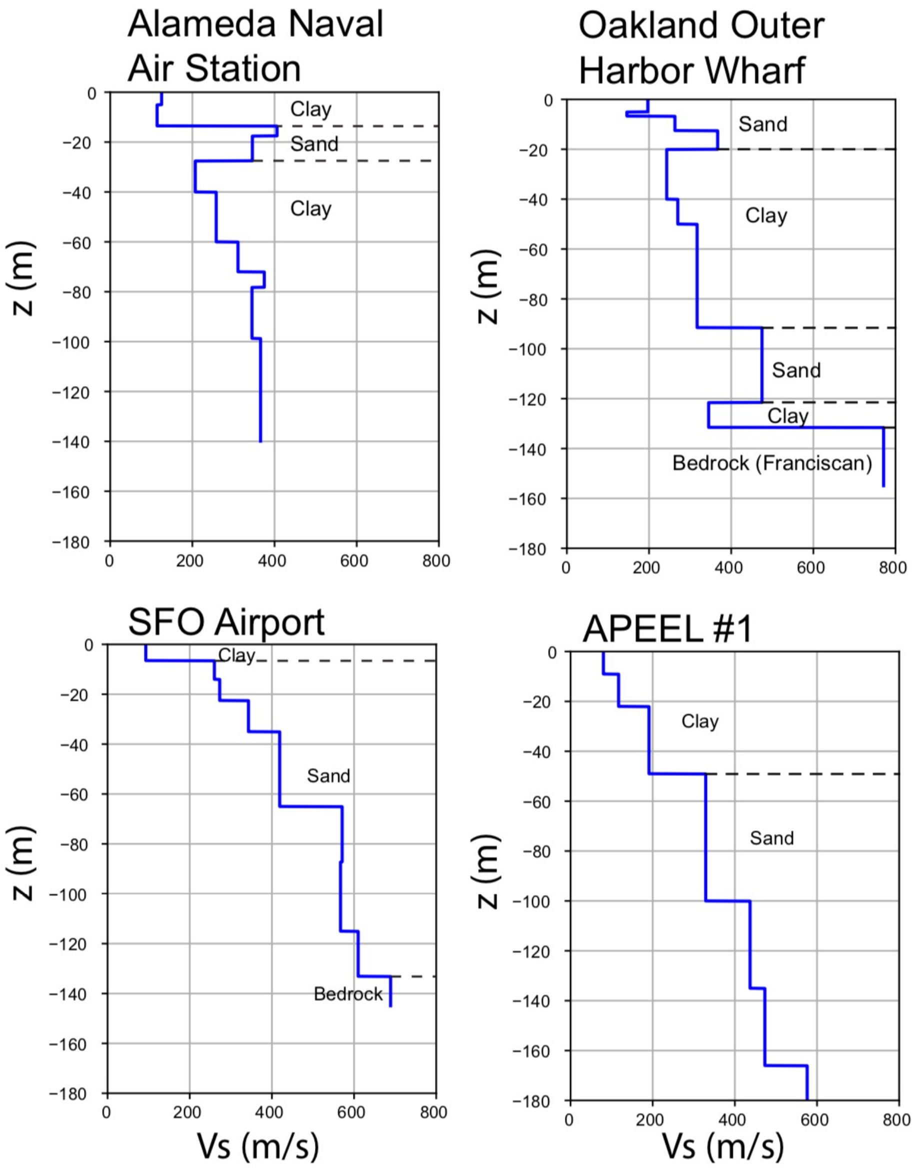


Consider each layer as a velocity-depth point and fit with power law (in log space)

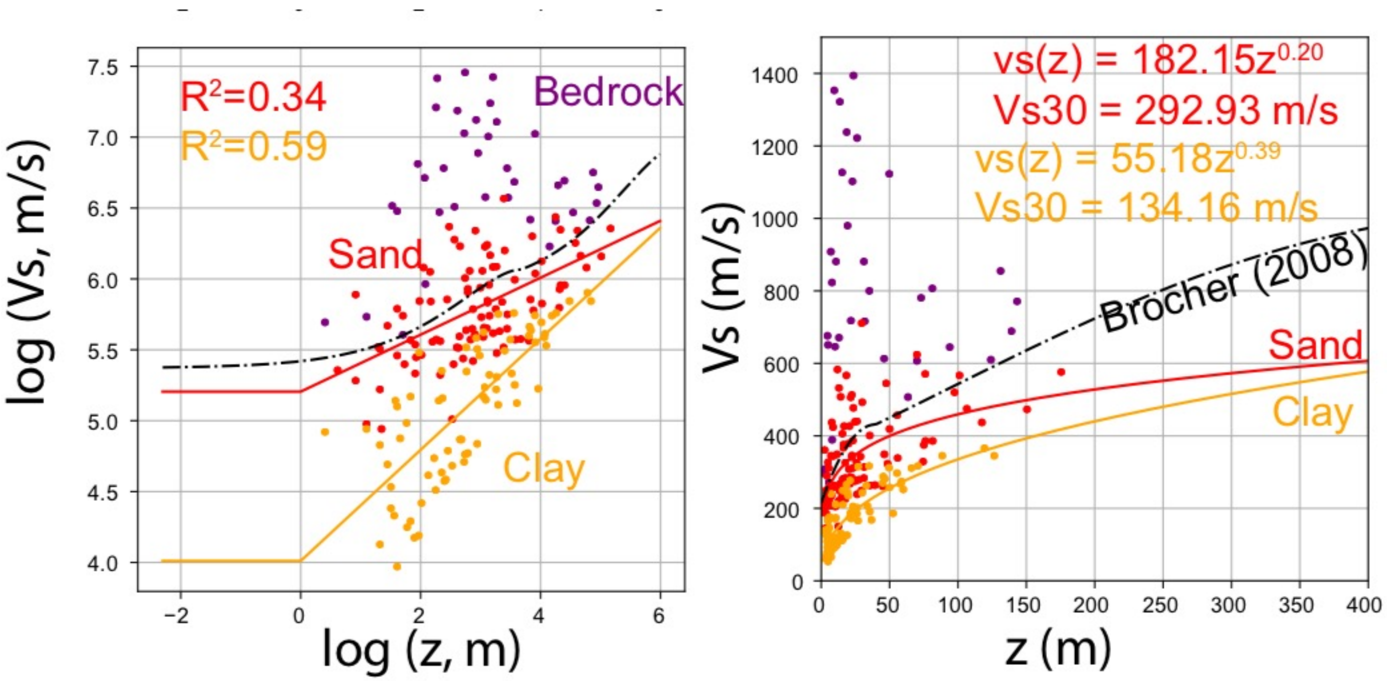


Resulting velocity-depth curve is probably too high for some SF Bay sediments, also a lot of variability

Categorize and refit the 1D layer data points based on rock type



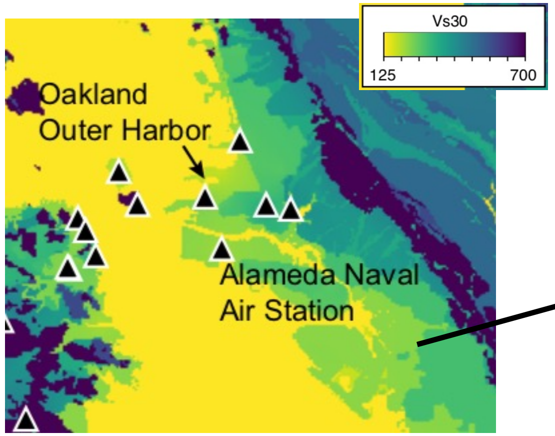
Gibbs et al., 1992



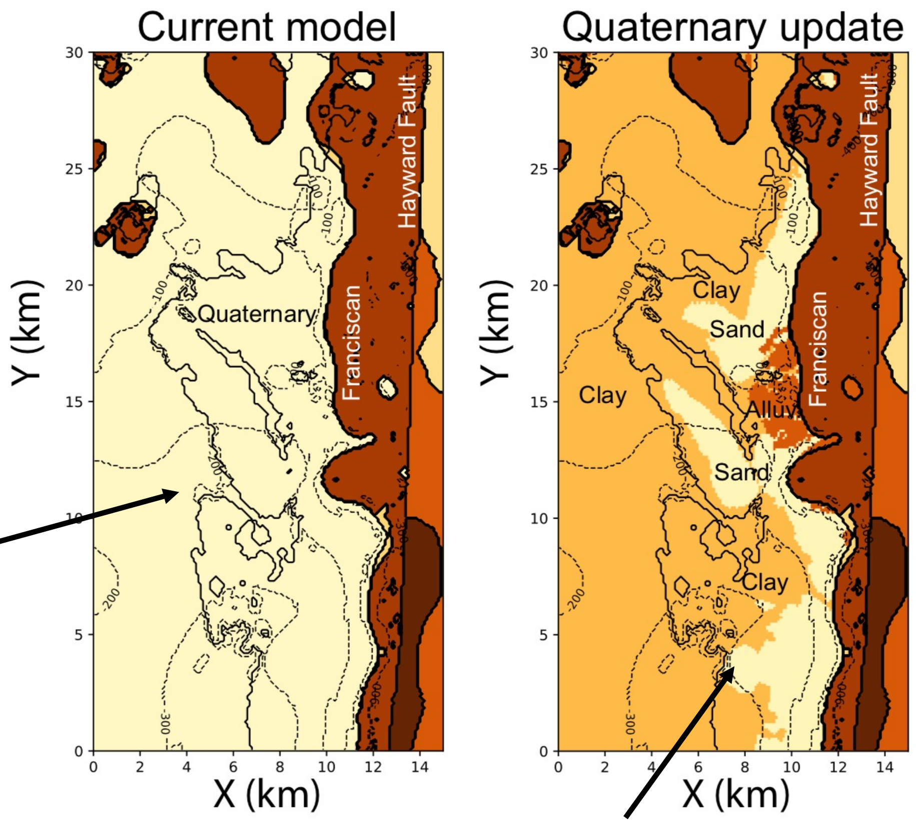
Fitting velocities for different rock types leads to better fit and lower velocities for clay

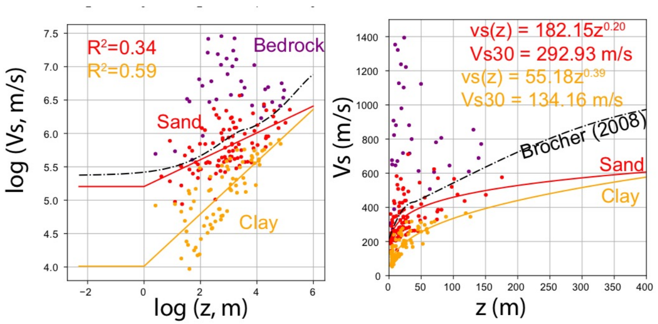
New velocity model in the Quaternary zone

Use Vs30 map (Thompson, 2018) to separate “clay” and “sand” in Quaternary geologic model zone

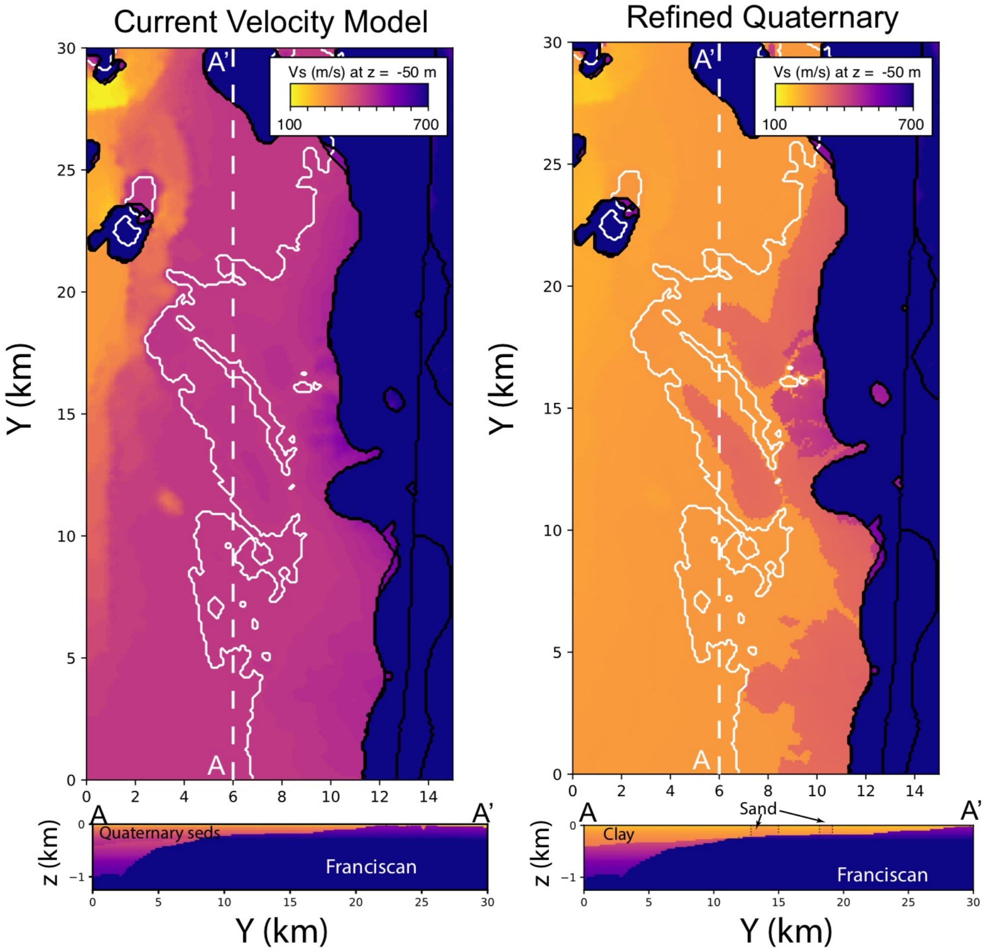


Geologic model

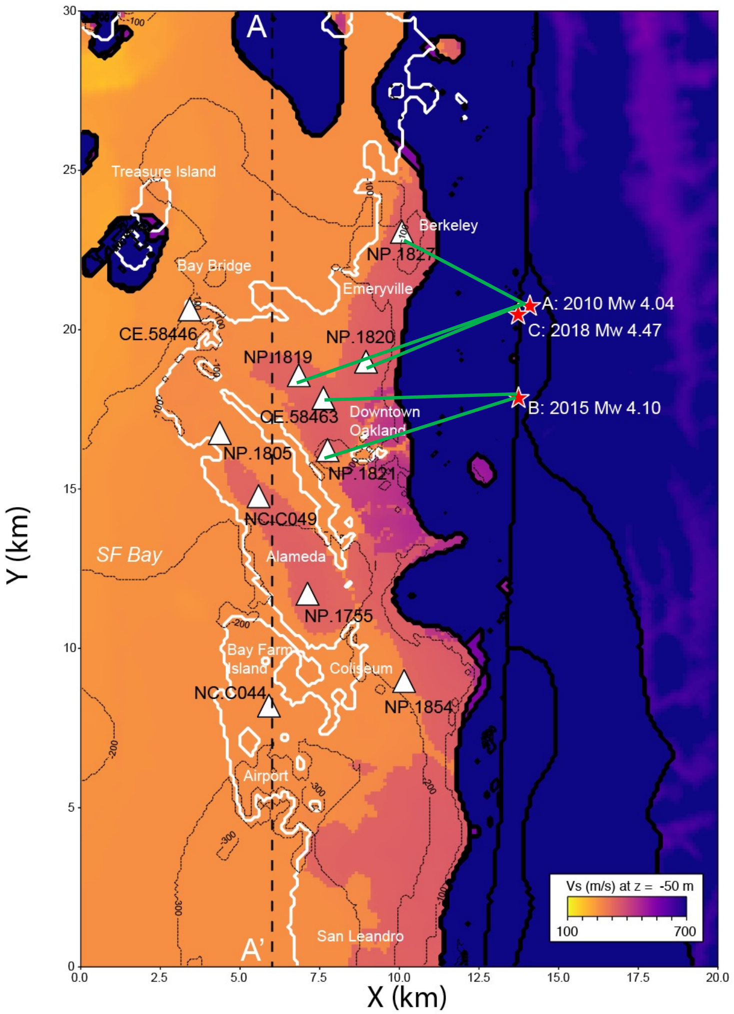


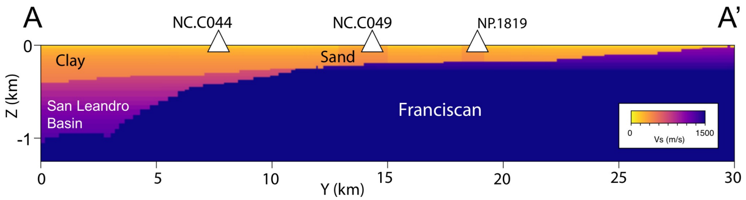


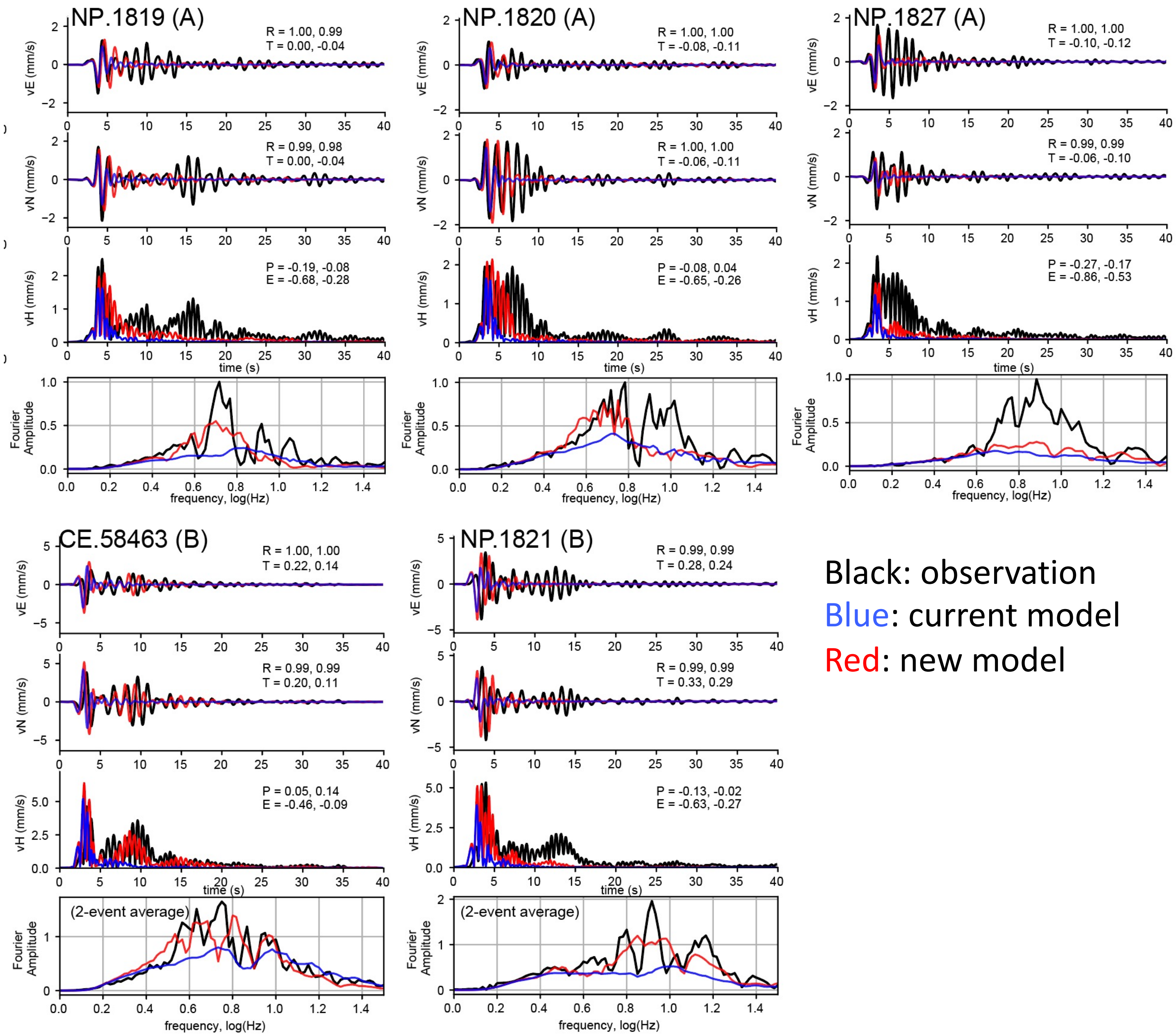
Velocity model



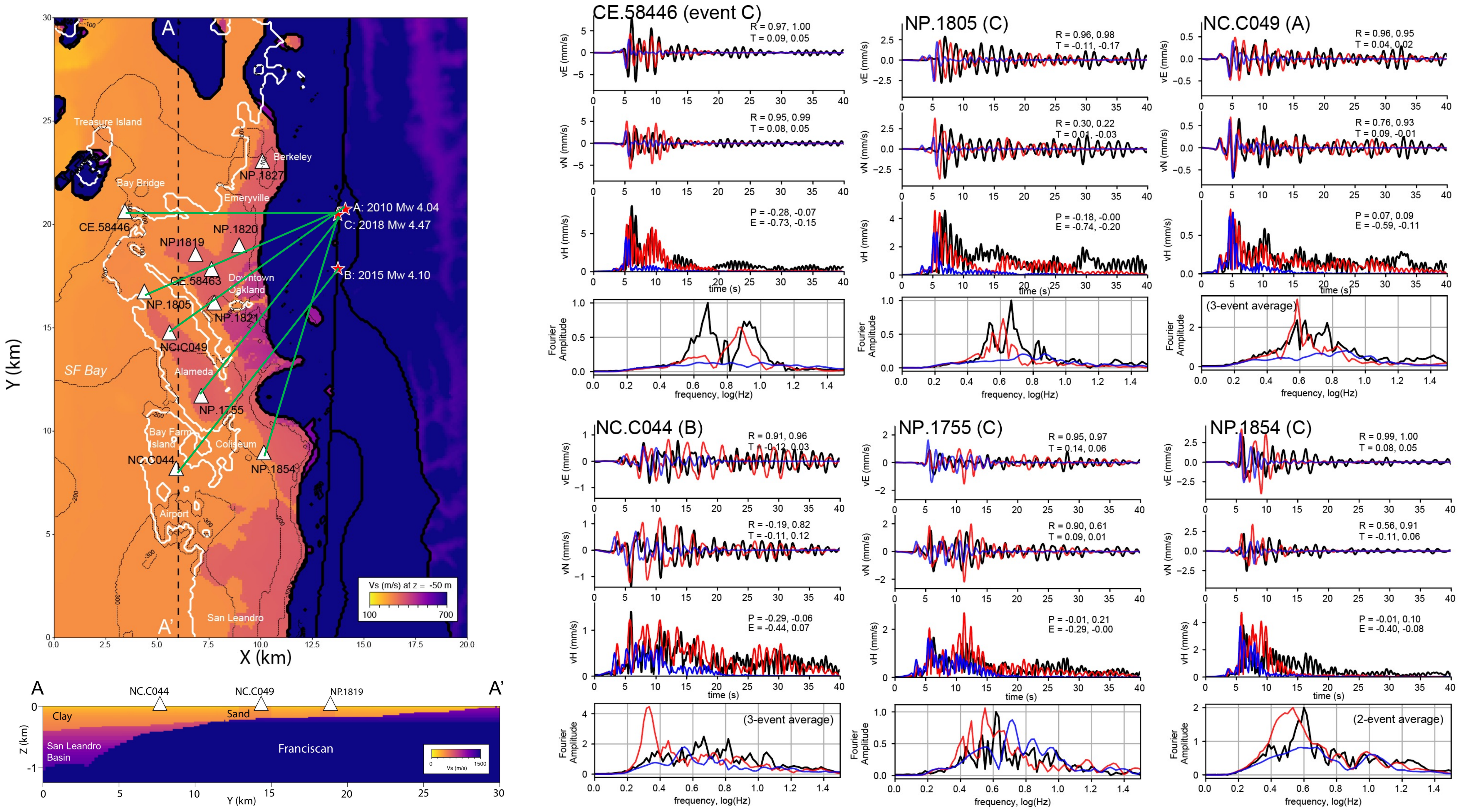
Simulations with new sediment relation (SW4, up to ~1.5 Hz)







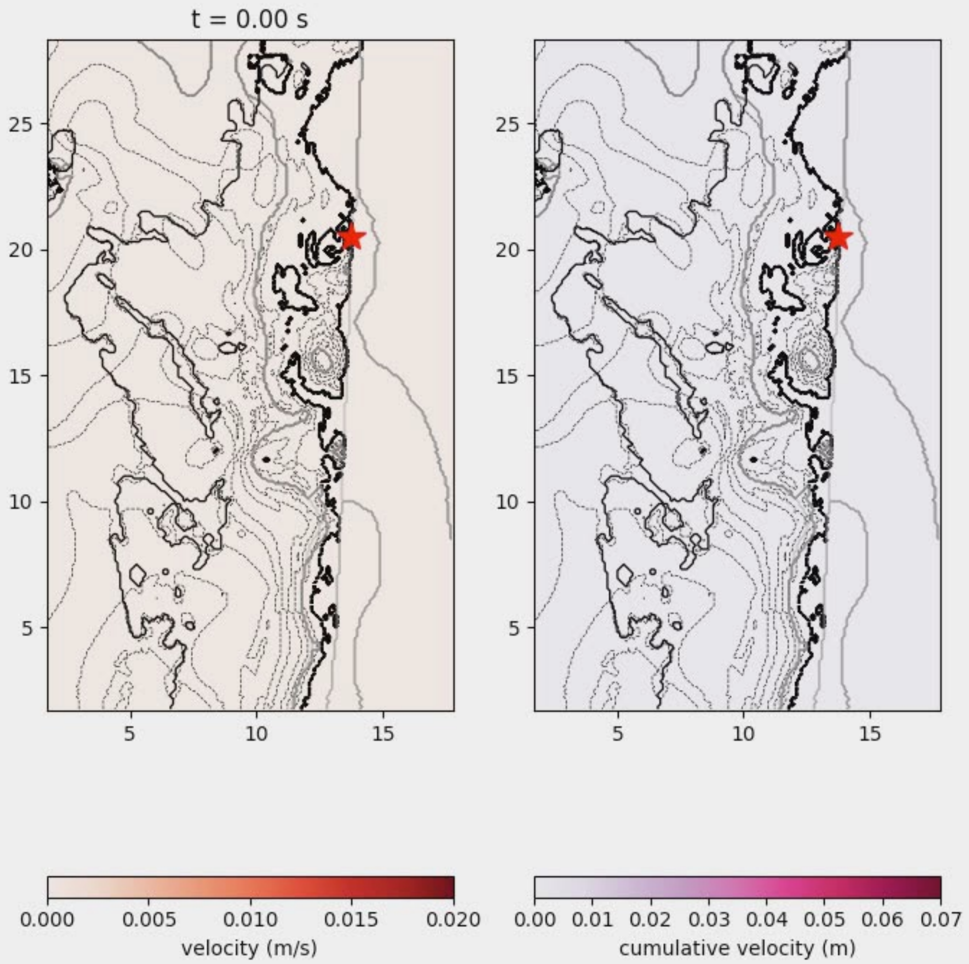
Black: observation
Blue: current model
Red: new model



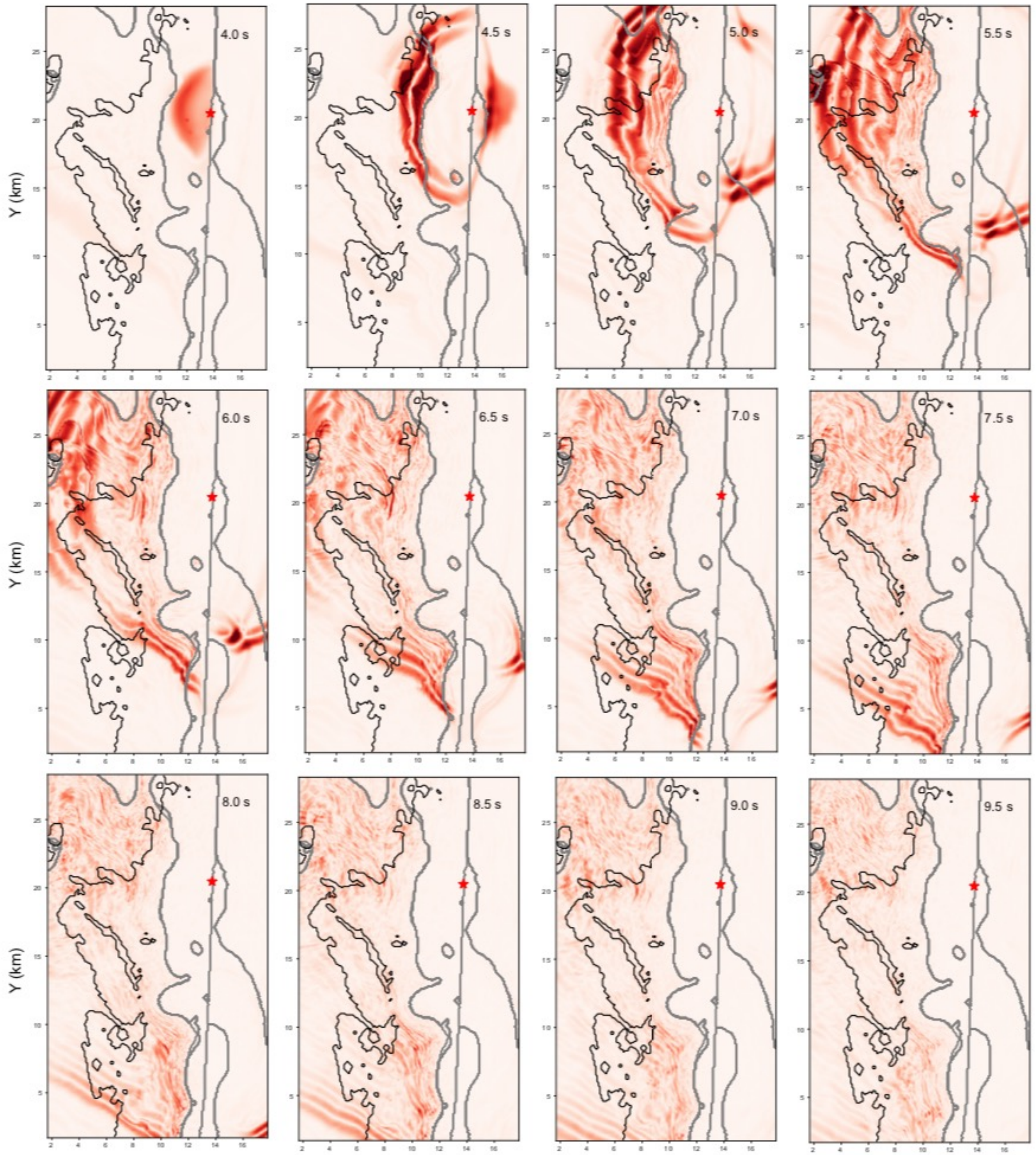
Treasure Island
Bay Bridge
Berkeley
NP.1827
Emeryville
CE.58446
NP.1820
NP.1819
CE.58463
Downtown Oakland
NP.1805
NP.1821
NC.C049
Alameda
SF Bay
NP.1755
Bay Farm Island
Coliseum
NC.C044
NP.1854
Airport
San Leandro
A: 2010 Mw 4.04
C: 2018 Mw 4.47
B: 2015 Mw 4.10
Vs (m/s) at z = -50 m
Y (km)
X (km)
Clay
Sand
San Leandro Basin
Franciscan
Z (km)
Y (km)
Vs (m/s)
CE.58446 (event C)
NP.1805 (C)
NC.C049 (A)
NC.C044 (B)
NP.1755 (C)
NP.1854 (C)
vE (mm/s)
vN (mm/s)
vH (mm/s)
time (s)
Fourier Amplitude
frequency, log(Hz)
(3-event average)
(2-event average)
R = 0.97, 1.00
T = 0.09, 0.05
R = 0.95, 0.99
T = 0.08, 0.05
P = -0.28, -0.07
E = -0.73, -0.15
R = 0.96, 0.98
T = -0.11, -0.17
R = 0.30, 0.22
T = 0.01, -0.03
P = -0.18, -0.00
E = -0.74, -0.20
R = 0.96, 0.95
T = 0.04, 0.02
R = 0.76, 0.93
T = 0.09, -0.01
P = 0.07, 0.09
E = -0.59, -0.11
R = 0.91, 0.96
T = -0.12, 0.03
R = -0.19, 0.82
T = -0.11, 0.12
P = -0.29, -0.06
E = -0.44, 0.07
R = 0.95, 0.97
T = 0.14, 0.06
R = 0.90, 0.61
T = 0.09, 0.01
P = -0.01, 0.21
E = -0.29, -0.00
R = 0.99, 1.00
T = 0.08, 0.05
R = 0.56, 0.91
T = -0.11, 0.06
P = -0.01, 0.10
E = -0.40, -0.08

2018 Mw 4.5 Berkeley earthquake simulation (animation) with new sediment model:

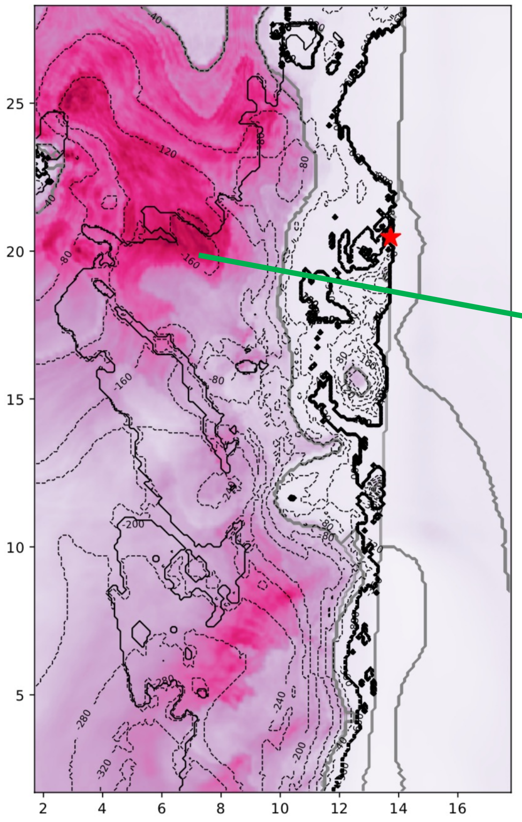
Wave propagation (left) and cumulative motion (right)



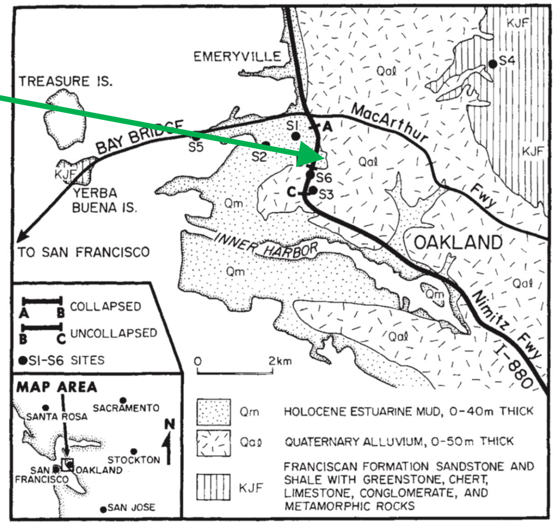
Ground Motion Snapshots



Simulated cumulative motions are high near boundary of sand/clay and in basin-like (concave bedrock surface) areas



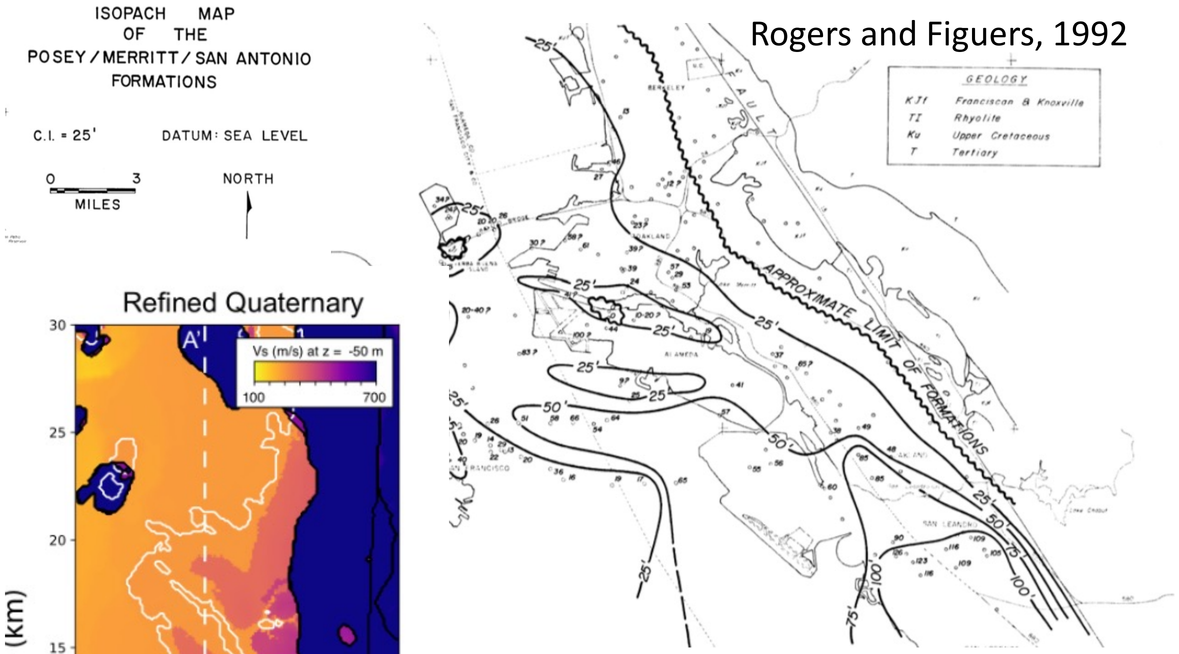
High cumulative shaking near areas of extreme structural damage in 1989

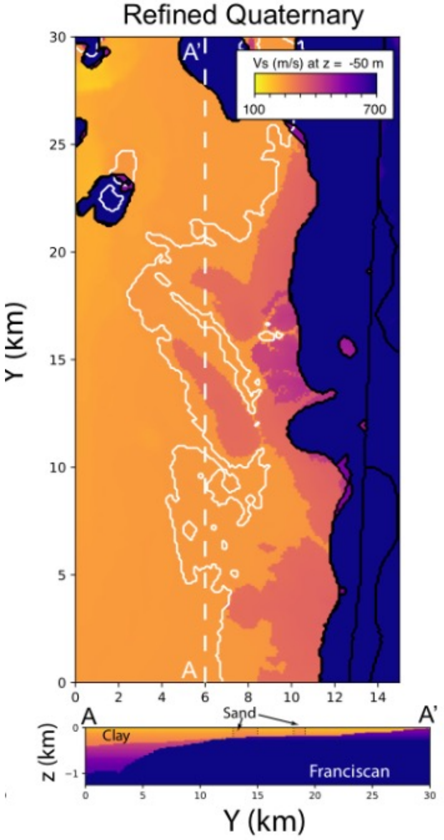


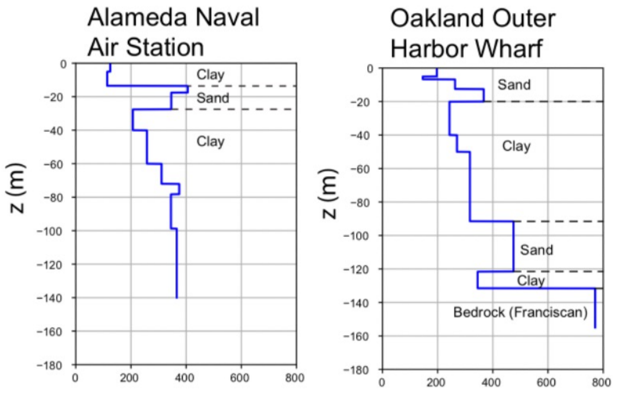
What now?

How to treat sands?

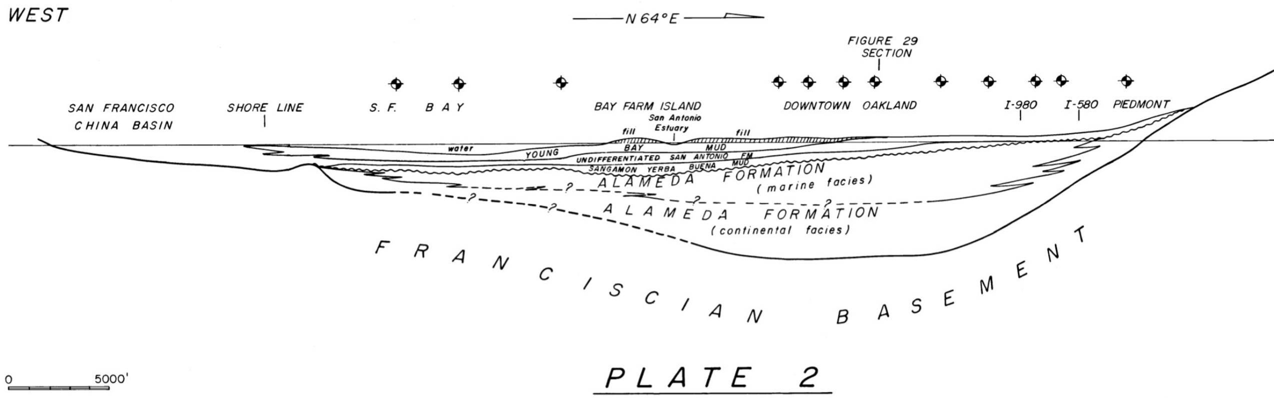
Rogers and Figuers, 1992





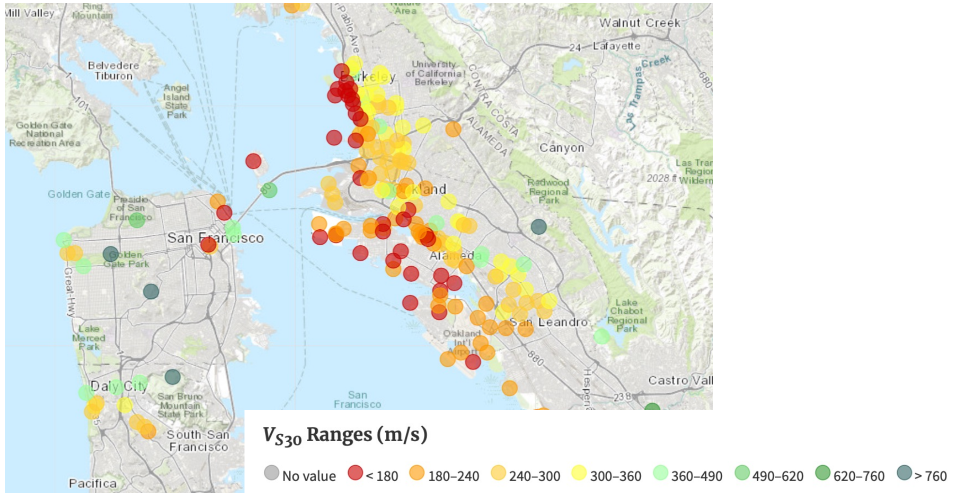


Should we build a better stratigraphic model?



Rogers and Figuers, 1992

Other Vs30 or surface data?



Conclusion

• We incorporate additional surface data into the USGS SF Bay region 3D seismic velocity model; our updates lowered velocities in the quaternary sediments around the SF Bay and increases the cumulative seismic motion.

• New lower velocity relations are fit for Bay Mud and sands around the SF Bay, and are combined with geologic distinctions from a Vs30 map to create the new model.

• The update allow more efficient trapping of seismic energy near the surface, but the cumulative motion is still too low compared to observations.