# Summary of NGA Models

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# NGA Project

- NGA-E (empirical)
  - New ground motion models based primarily on empirical data
  - Use analytical models (seismological and geotechnical) to guide extrapolation outside of empirical data
    - Results used only in terms of scaling
- NGA-H (hybrid)
  - New ground motion models based on both empirical data and numerically simulated data
    - Uses the values of the ground motion from the simulations, not just scaling

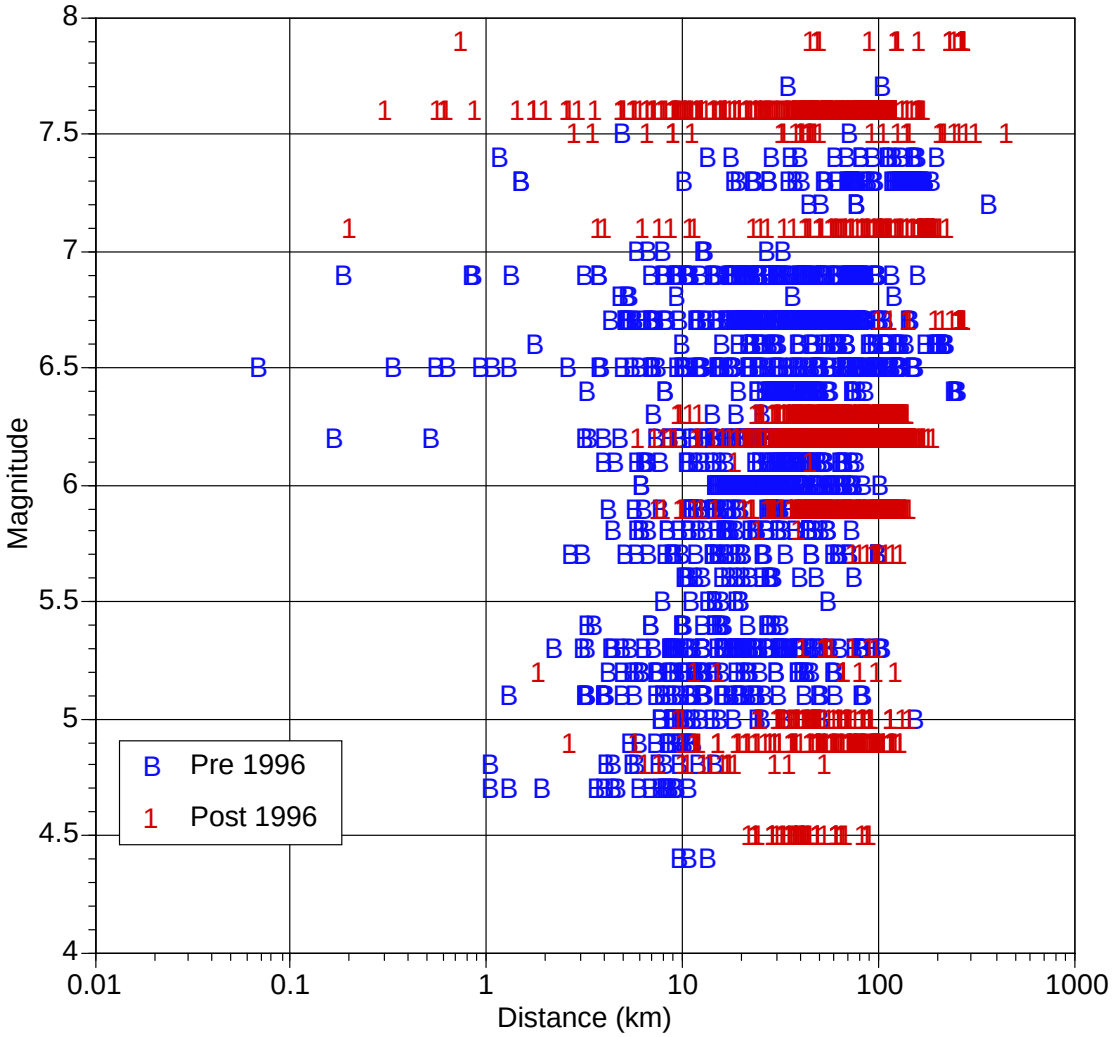
# NGA-E Project

- Ground motion models for crustal earthquakes in California
- Must be applicable to all design cases in California (excludes subduction)
  - Ground Motion Parameters:
    - Horizontal components (Ave Horiz, FN, and FP)
    - PGA, PGV, PGD
    - Pseudo spectral acc at 5% damping: 0-10 sec
  - Applicable Magnitude Range:
    - 5.0 - 8.5 (SS)
    - 5.0 - 8.0 (RV)
  - Applicable Distance Range:
    - 0 - 200 km
  - Fault Types
    - Strike-slip, Reverse, Normal

# Ground Motion Model Developers

- Abrahamson & Silva
- Boore
- Campbell & Bozorgnia
- Chiou & Youngs
- Idriss

# Data Set Size



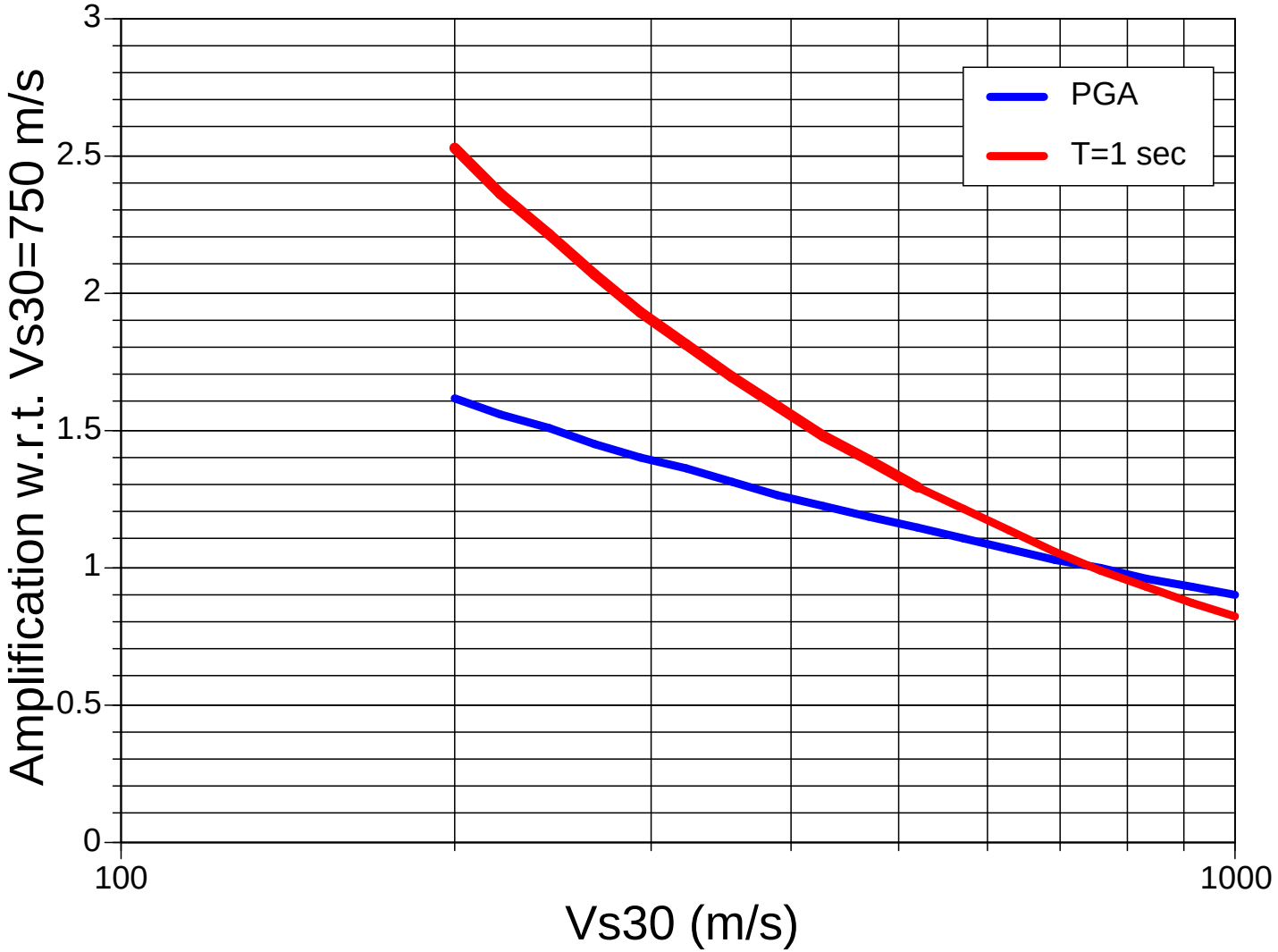
# Main Changes from Current Models

- Use of Vs30
- Standard deviation independent of mag
- Non-linear site response
- Hanging wall and Footwall factors
- Additional predictive parameters

# Use of Vs30

- All NGA models using Vs30
- Some of the reduction in ground motion is just due to the use of Vs30 rather than generic rock

# Vs30 Scaling (Linear)



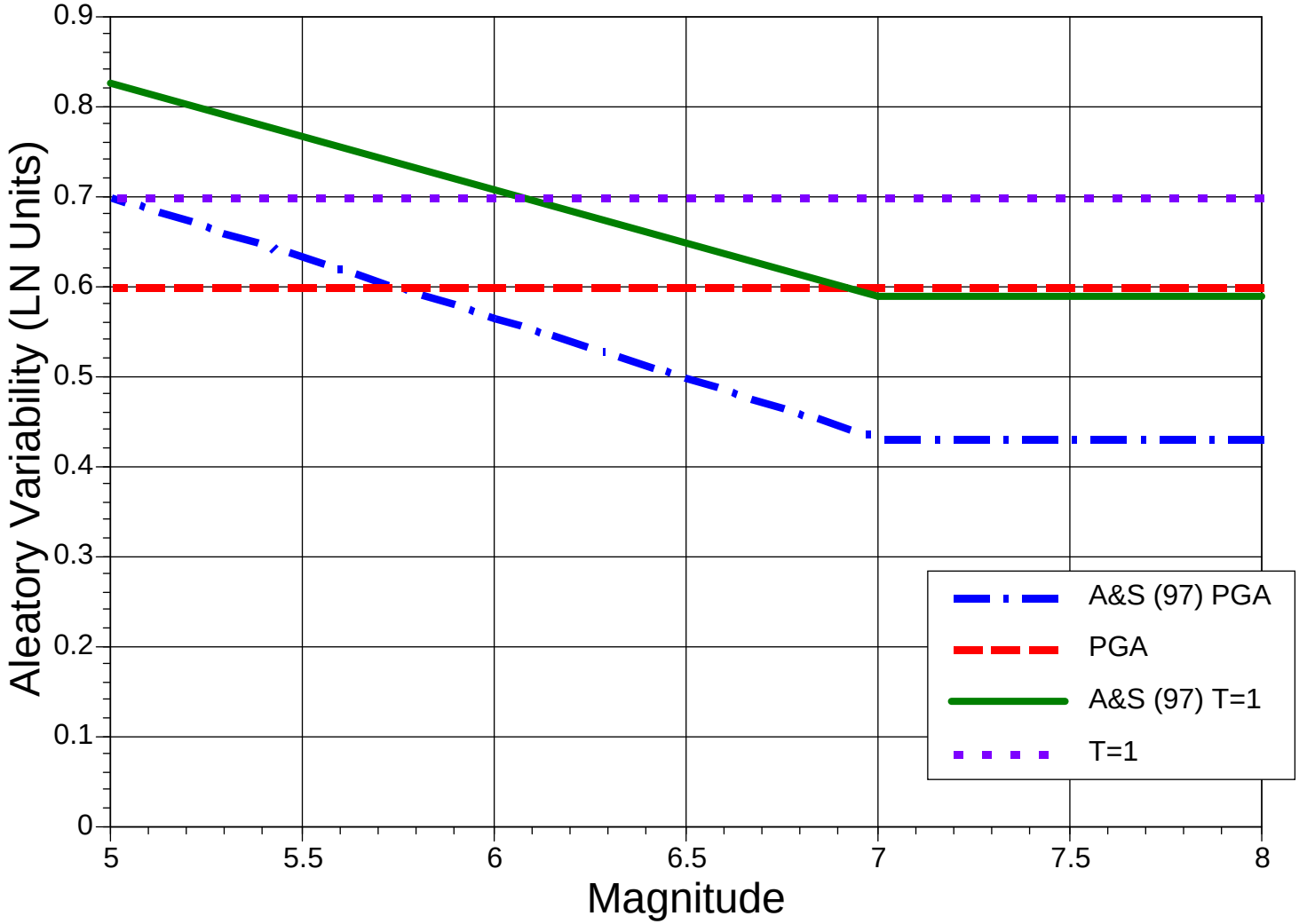
# Generic Rock and Vs Based Models

- Generic Rock categories
  - Many previous studies had incorrect classification of site
  - Vs30 approx 550 m/s for A&S 1997 generic rock
- Expect a reduction in the ground motion model jto account for Vs30 differences
  - If increase Vs30 from 550 to 750m/s
  - 12% decrease for PGA
  - 25% decrease for T= 1 sec

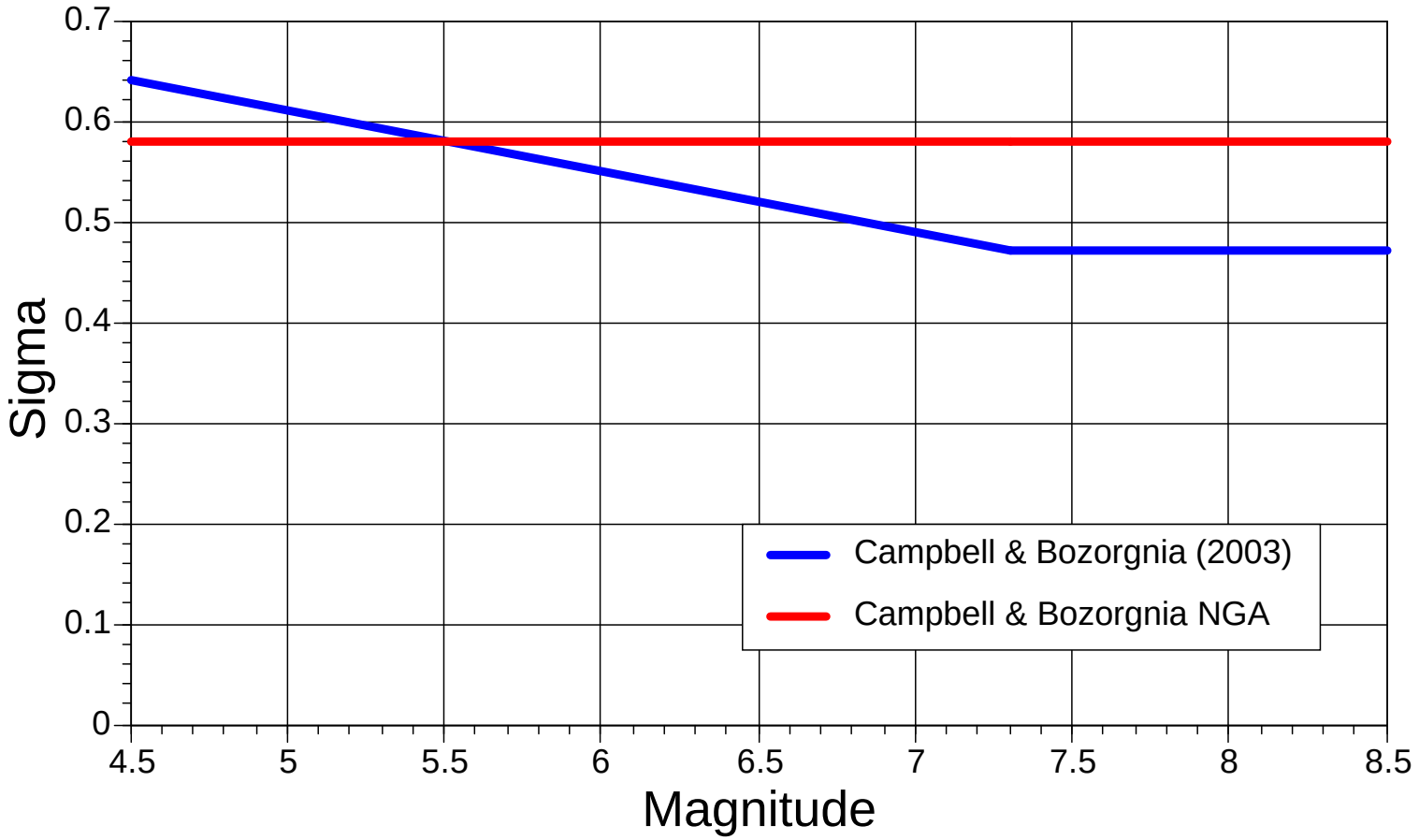
# Aleatory Variability

- Very similar rock variability for 4 of 5 NGA developers
  - Preliminary model from Idriss has larger varibaility
- No or weak magnitude dependence
  - NGA sigma is similar to previous models for M=6

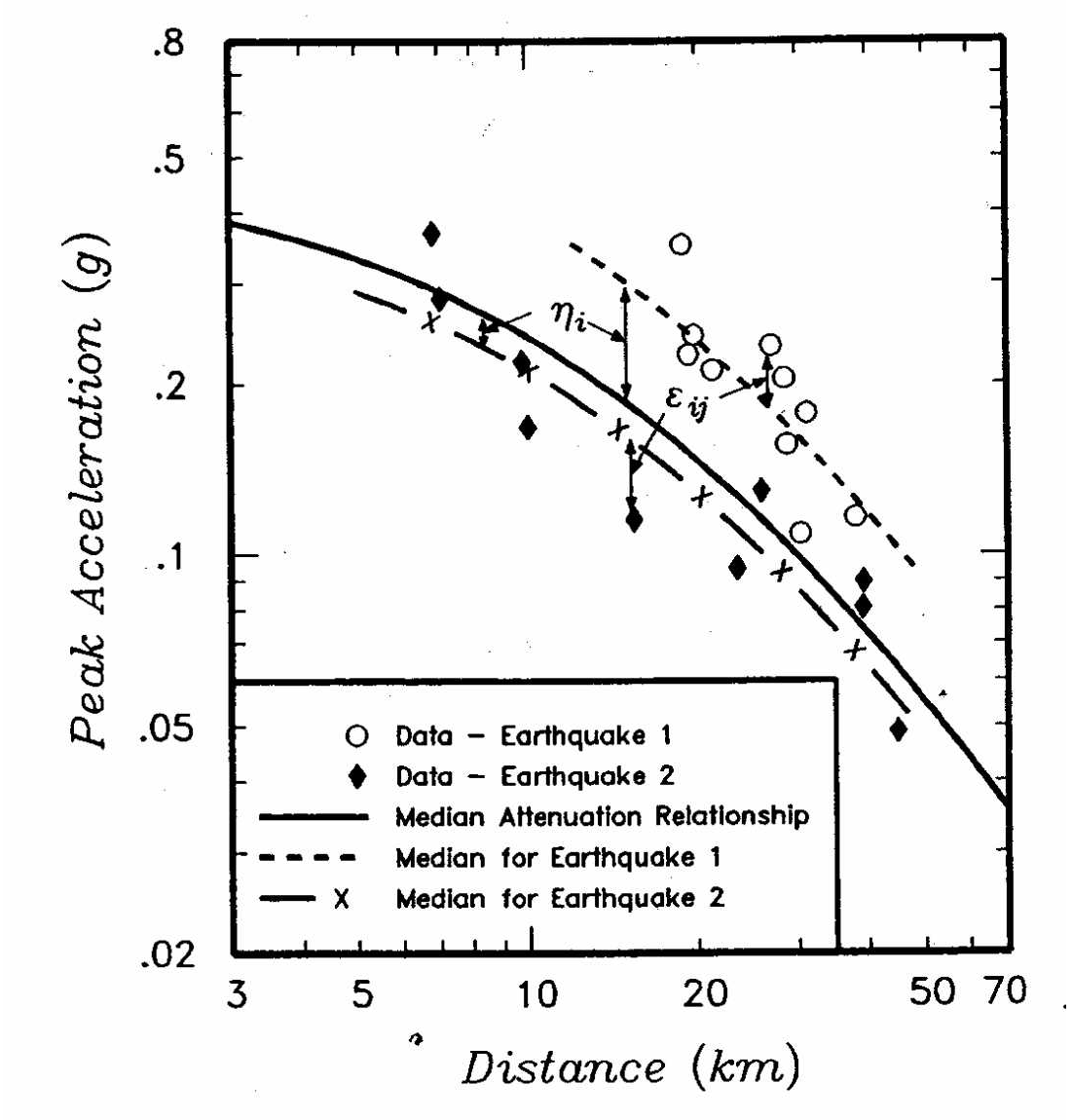
# Aleatory Variability (Rock)



# Campbell & Bozornia Sigma PGA

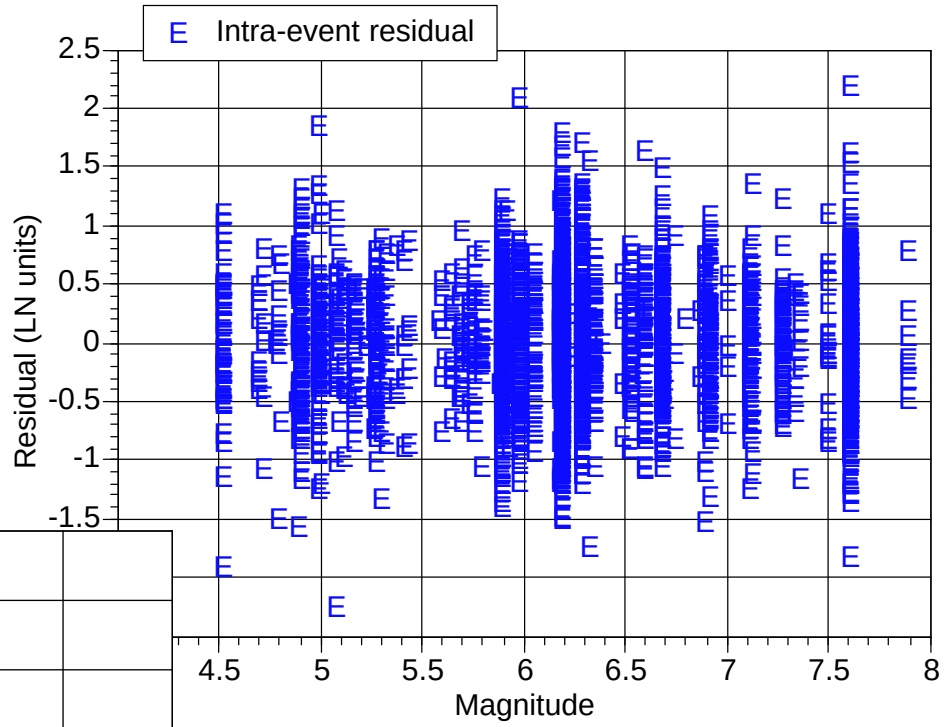


# Inter-Event and Intra-Event Terms

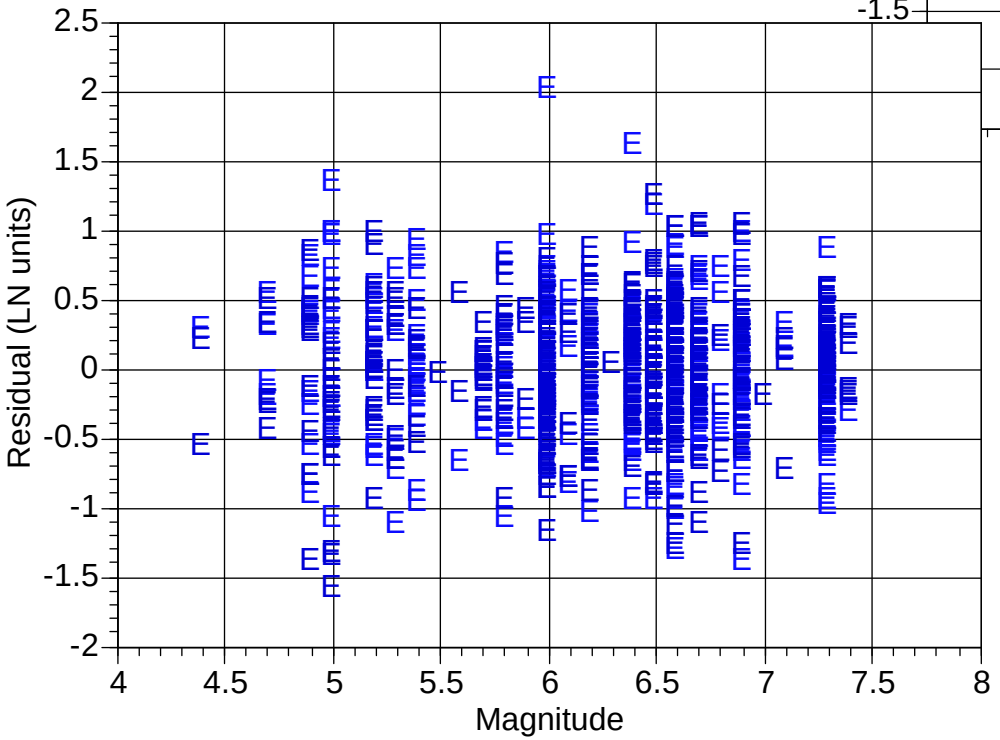


# Intra-Event PGA Residuals

NGA A&S 2005

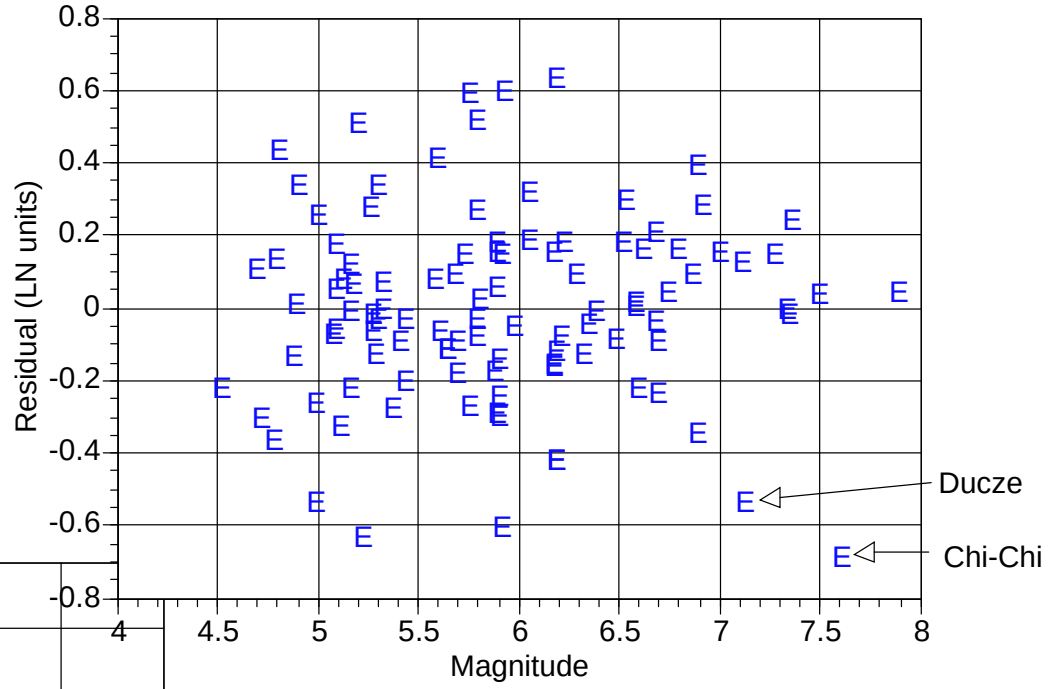



1997 A&S

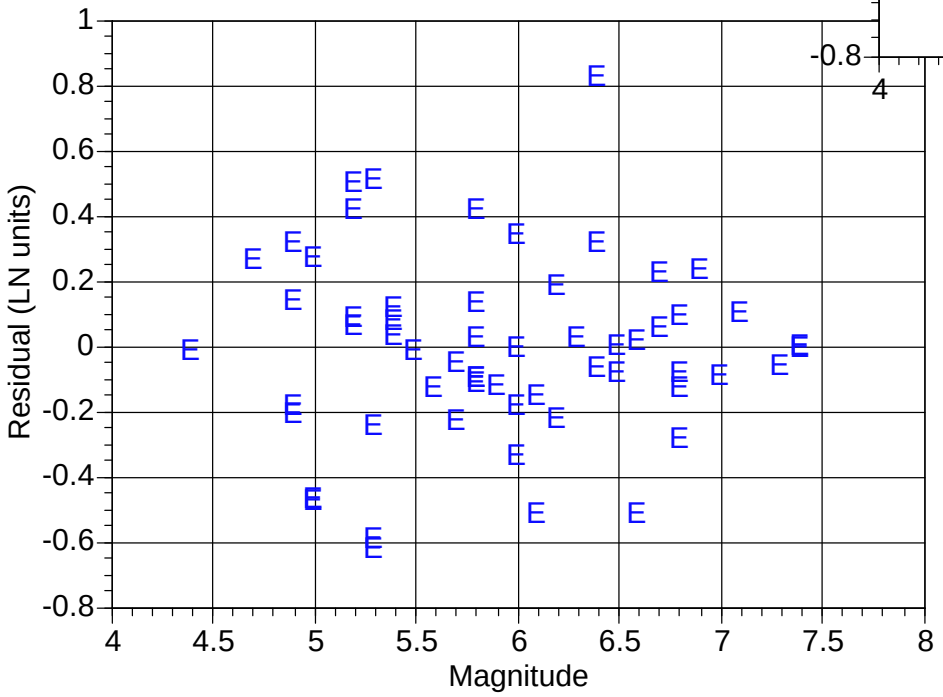


# Inter-Event PGA Residuals

NGA A&S 2005



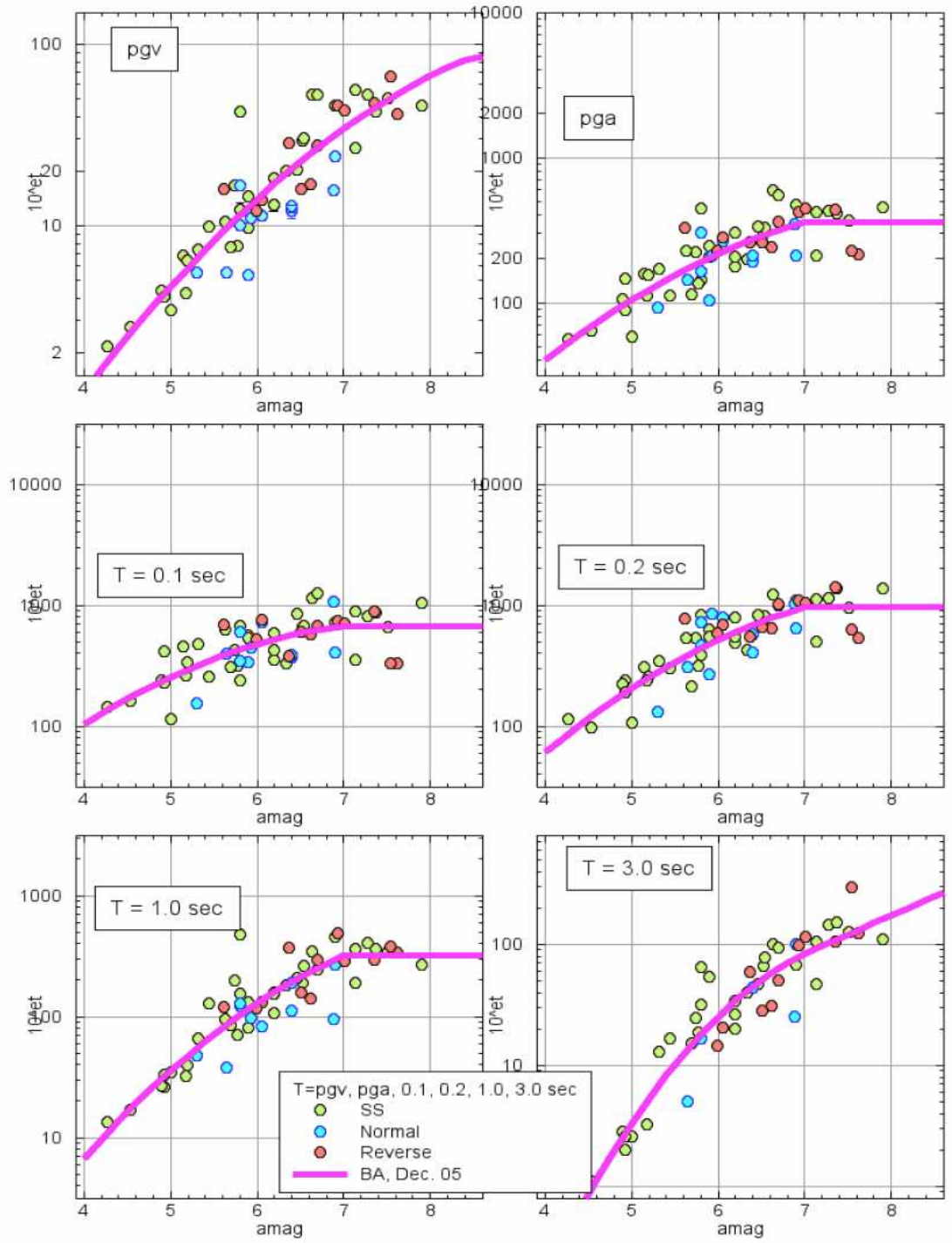

1997 A&S



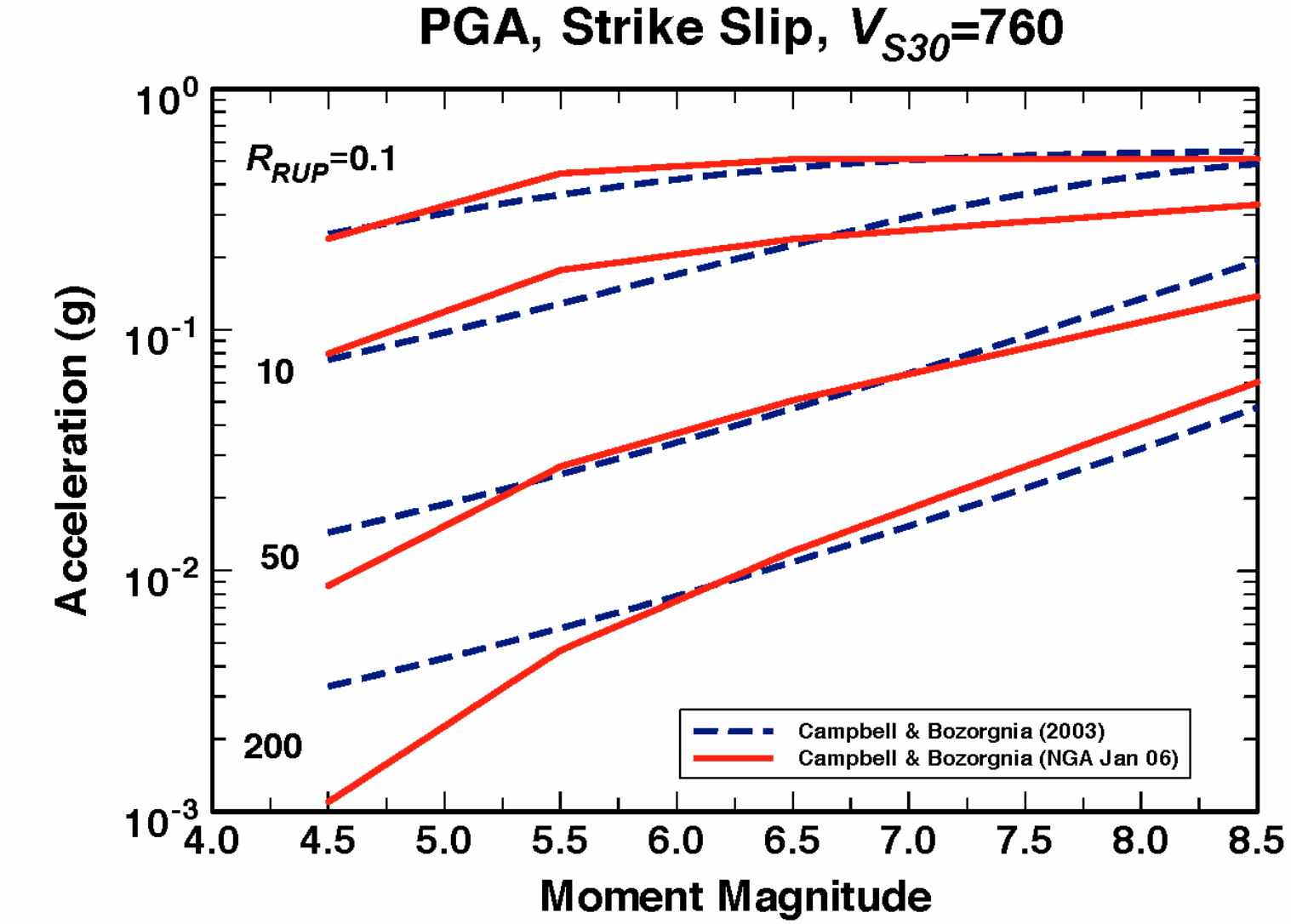
# Magnitude Dependence of Standard Deviation

- Intra-event standard deviation
  - 1999 Chi-Chi mainshock (M7.6) $\sigma$=0.55 increased estimate for large magnitudes
  - Additional small magnitude earthquakes decreased estimate for small magnitudes
- Inter-event standard deviation
  - 1999 Chi-Chi and 1999 Duzce increased estimate for large magnitudes
    - Large negative residuals
  - Additional small magnitude earthquakes decreased estimate for small magnitudes

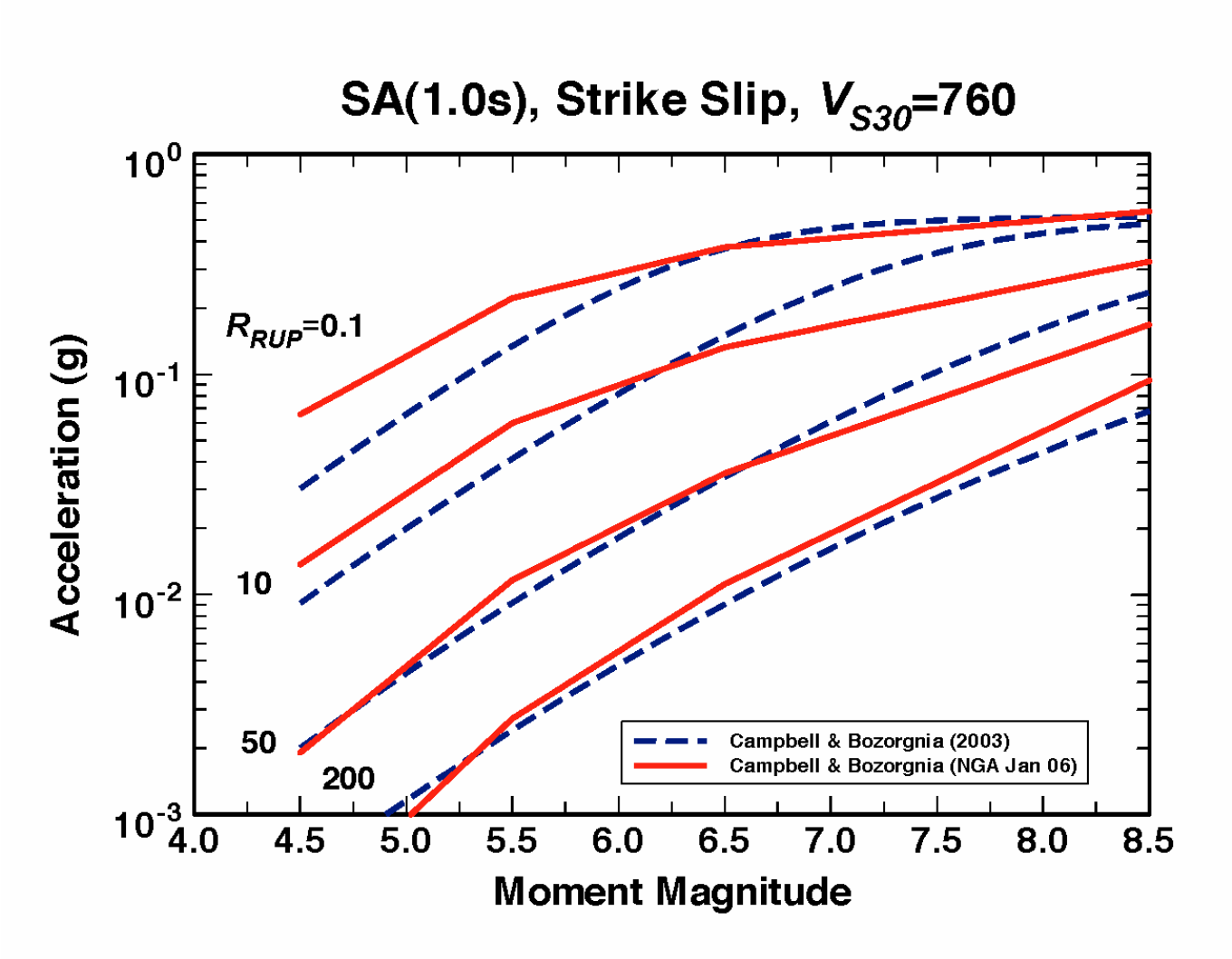
# Mag Scaling from Boore & Atkinson



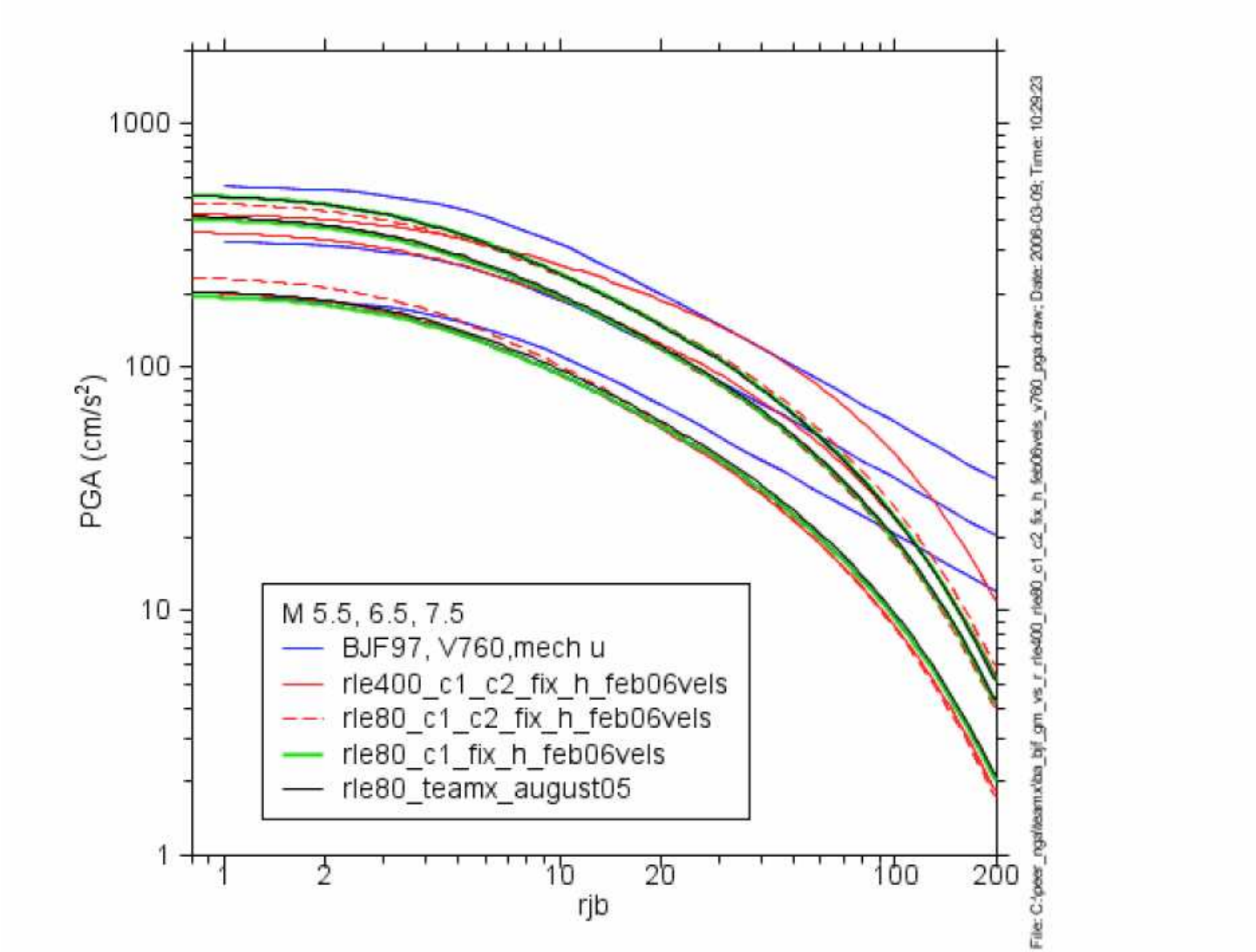
# Mag Scaling from Campbell & Bozorgnia



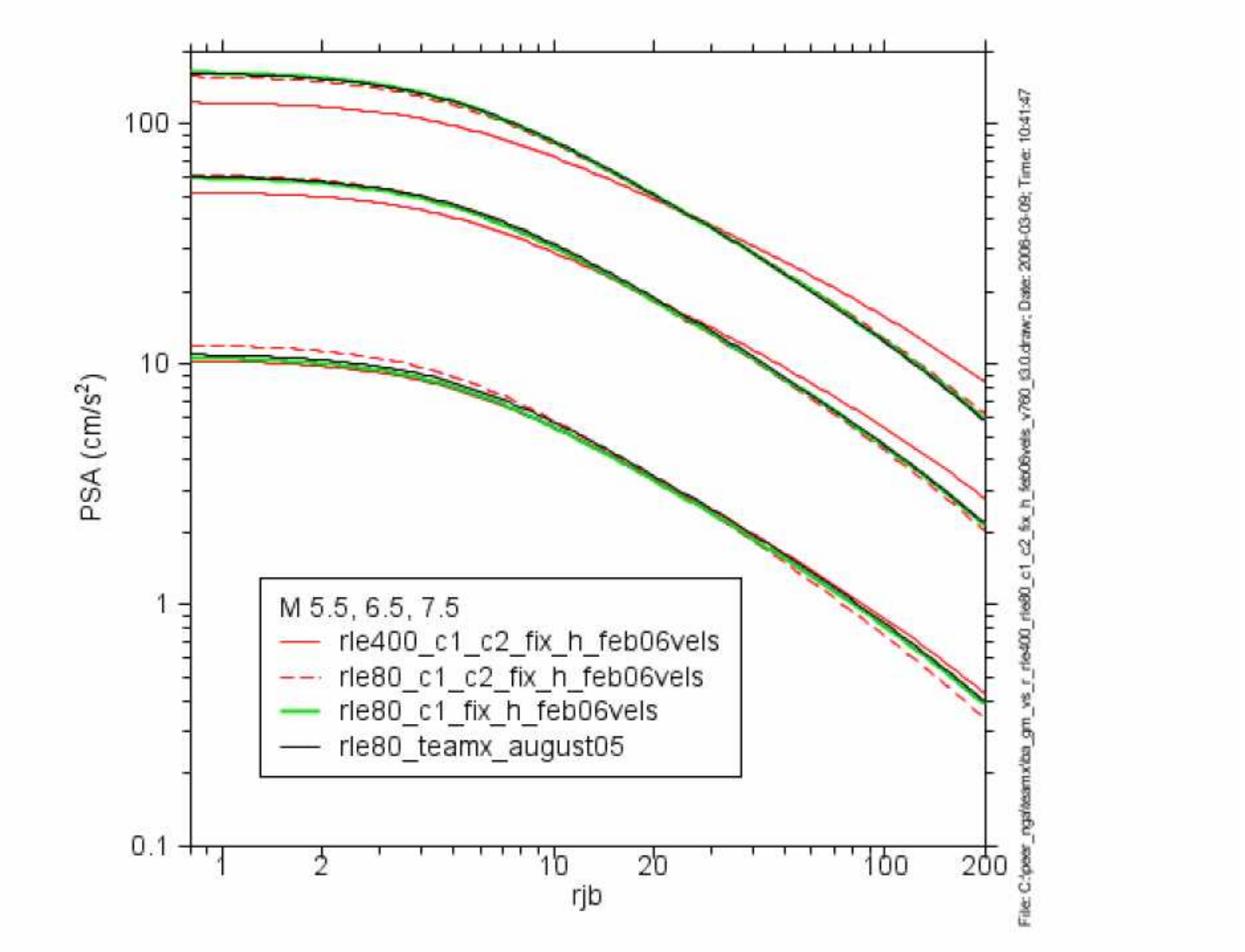
# Mag Scaling from Campbell & Bozorgnia



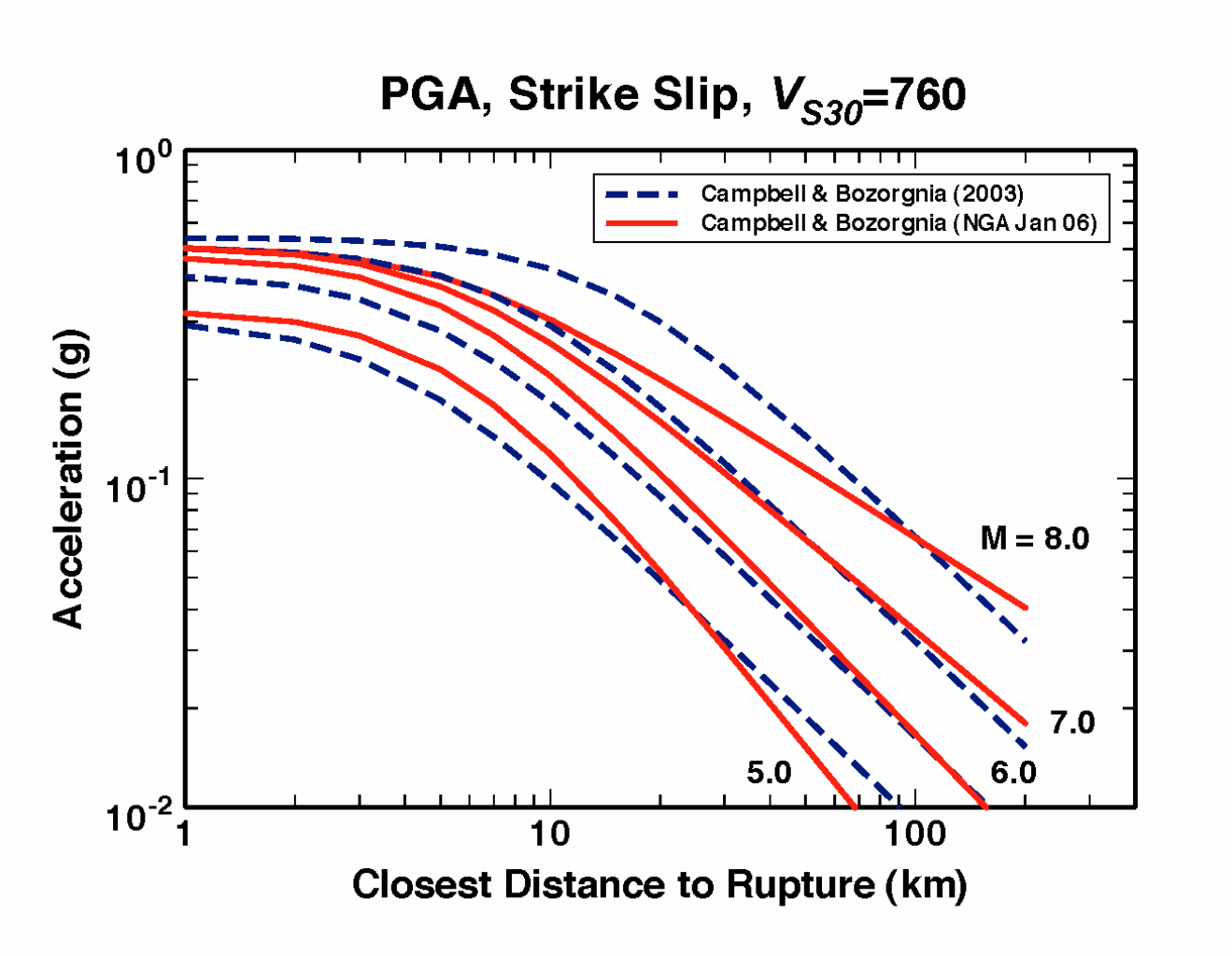
# PGA: Distance Scaling B&A Vs=760



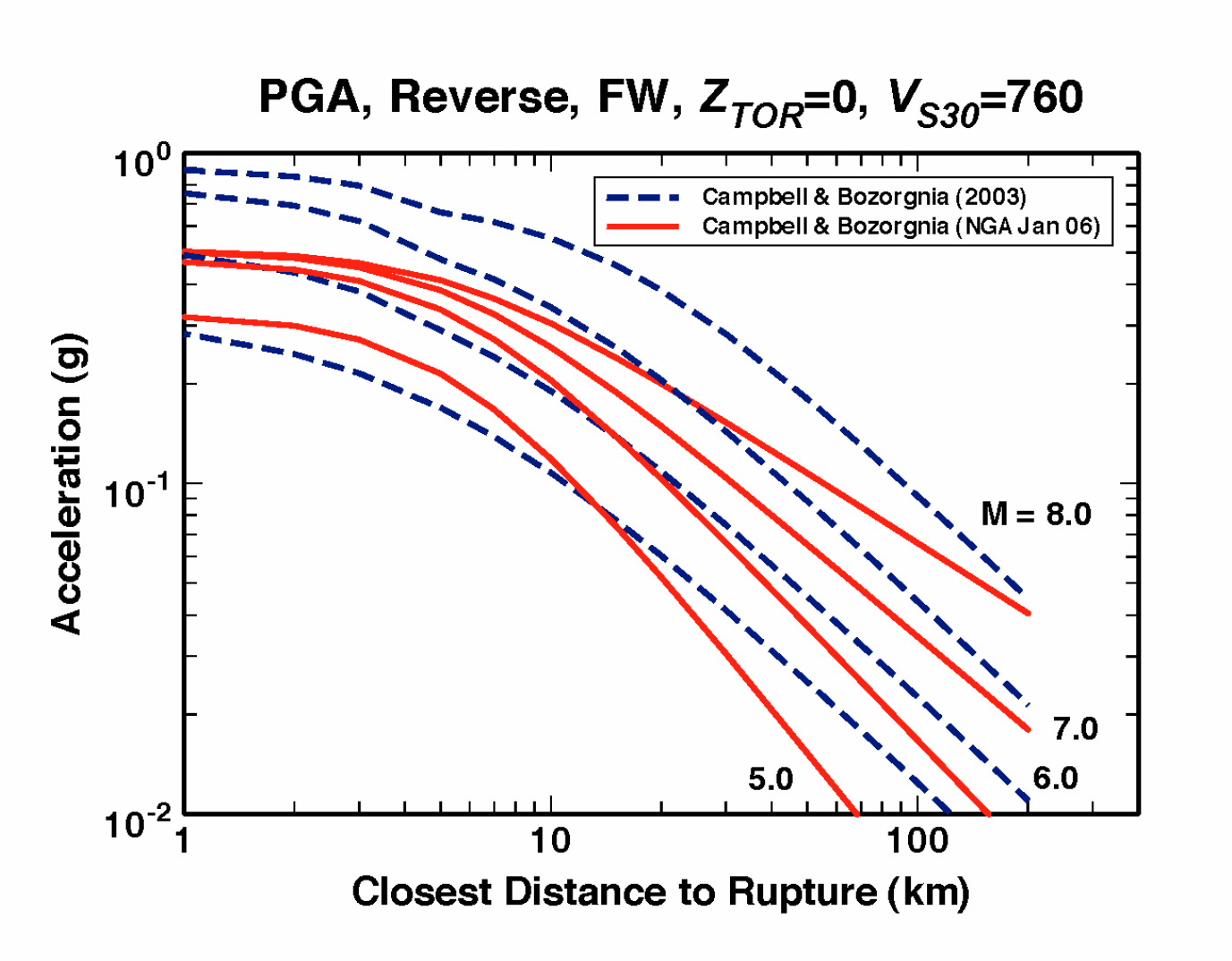
# T=1: Distance Scaling B&A Vs=760



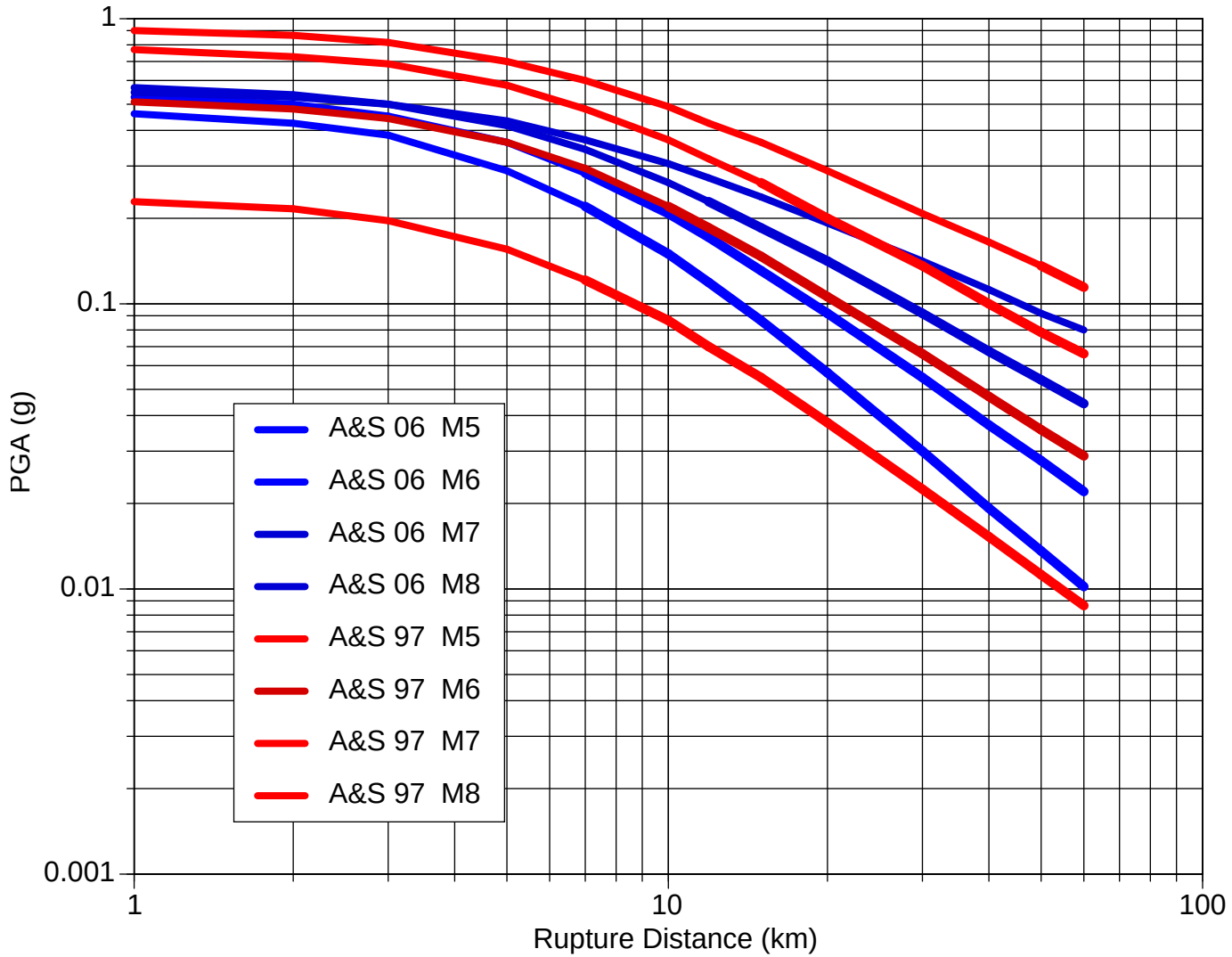
# PGA: Distance Scaling C&B Vs=760



# PGA: Distance Scaling C&B Vs=760



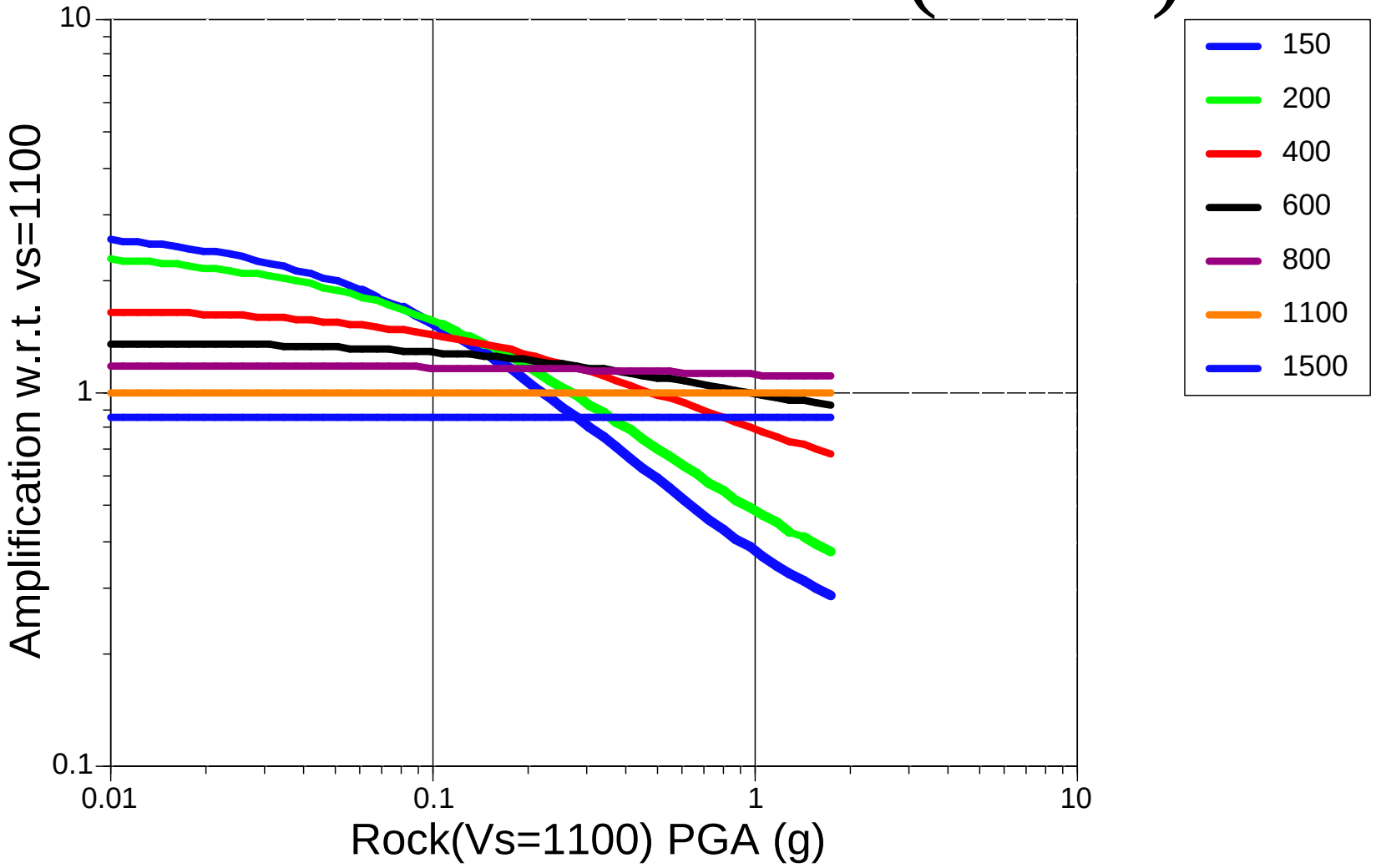
# A&S: PGA, SS, Vs=760



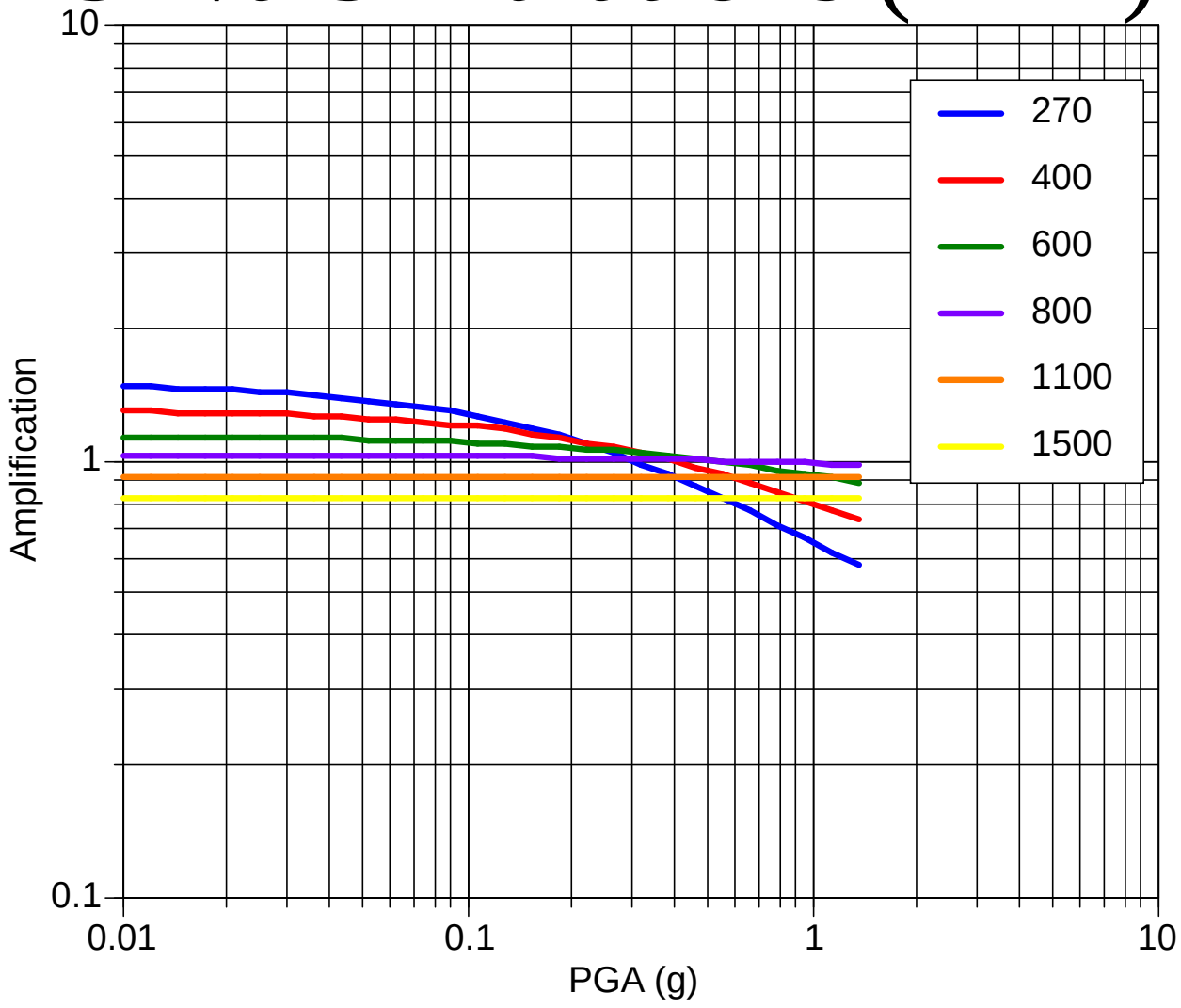
# Non-linear site response

- All developers include non-linear soil response
  - A&S, C&B constrain nonlinearity using analytical modeling from Silva
  - C&Y use empirical data
    - Chi-Chi afterhsocks important for empirical estimation
  - B&A use Stewart amp factors
  - Idriss approach not selected

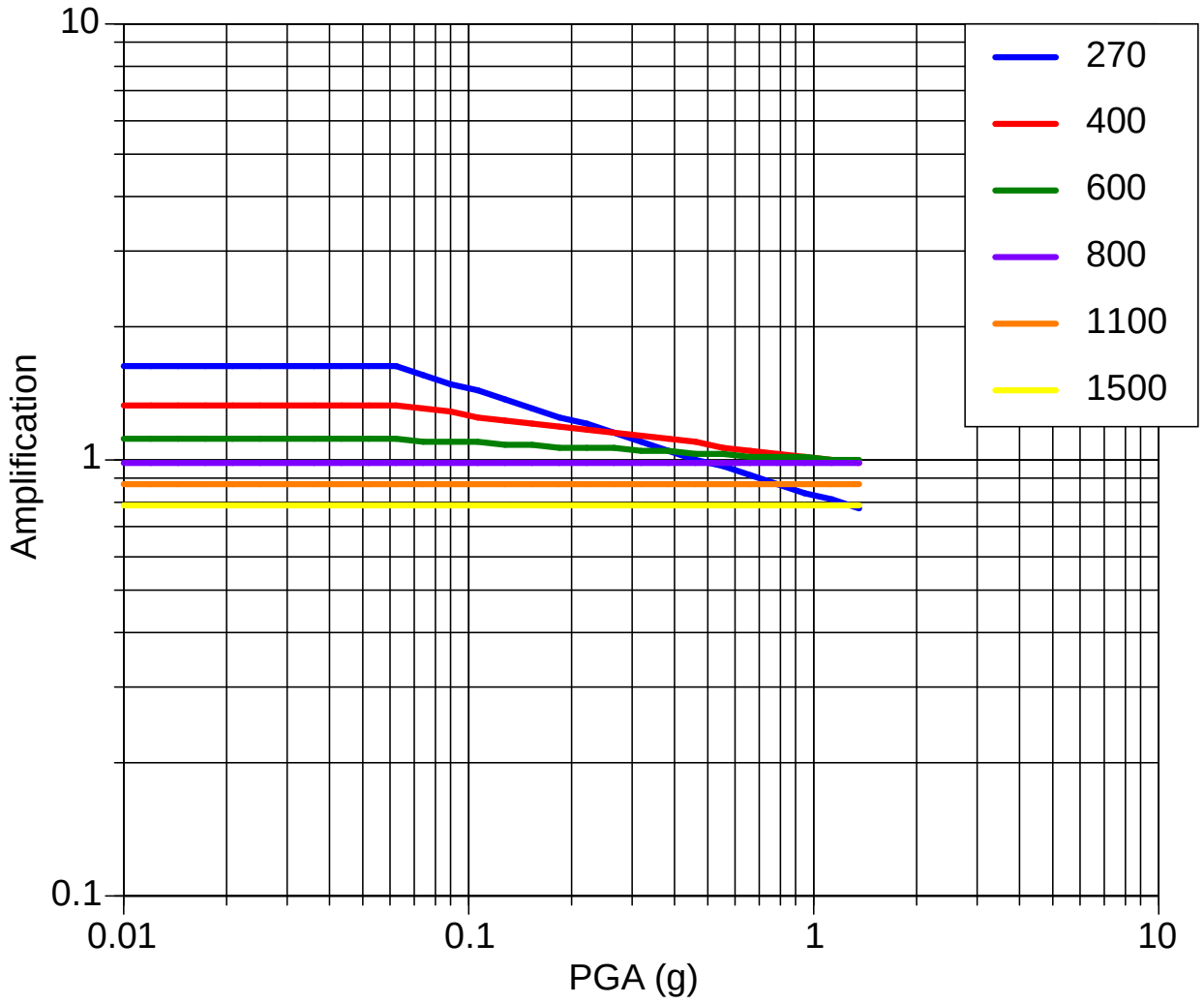
# PGA Amplification based on Silva Simulations (EPRI)



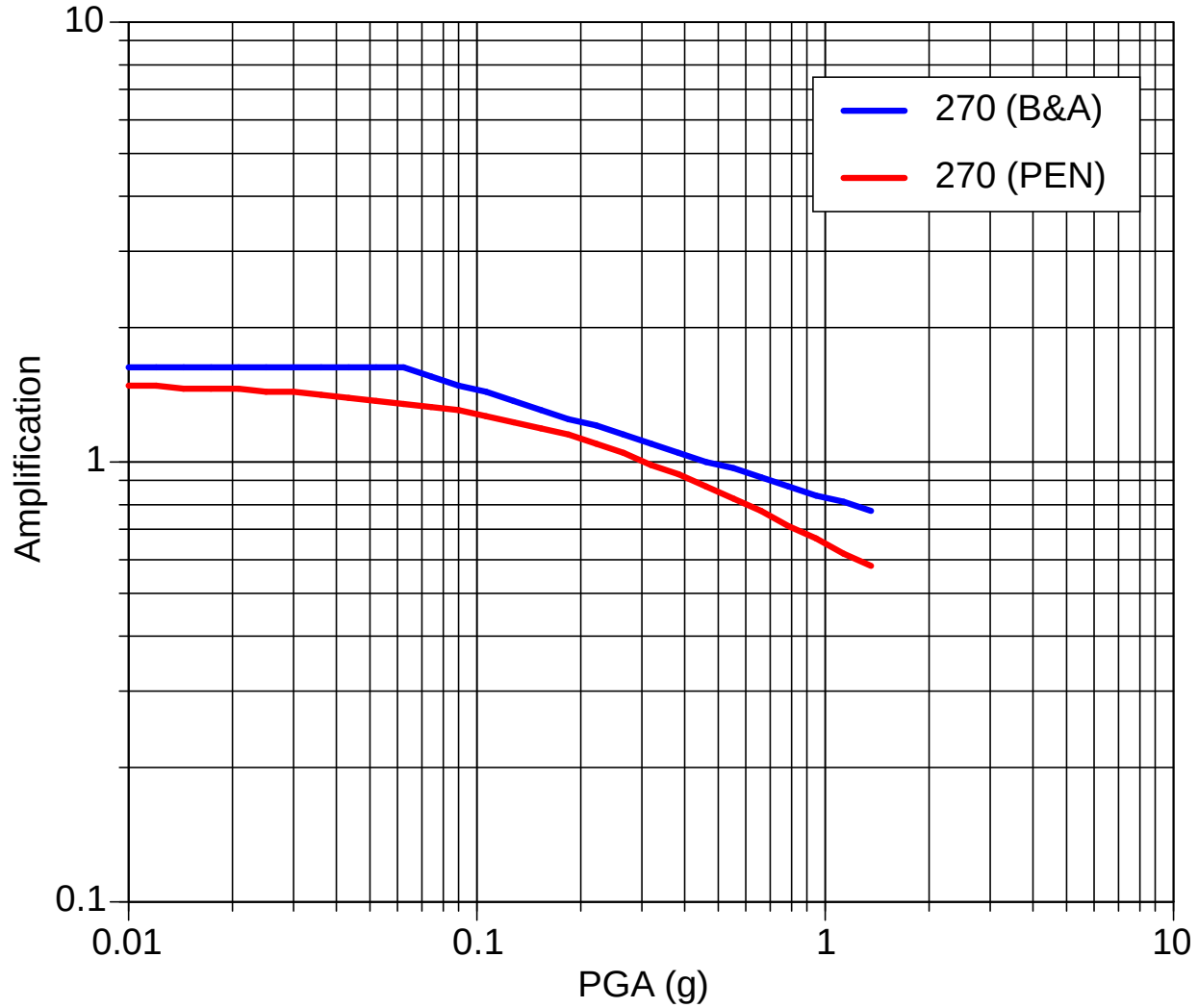
# PGA Amplification based on Silva Simulations (PEN)



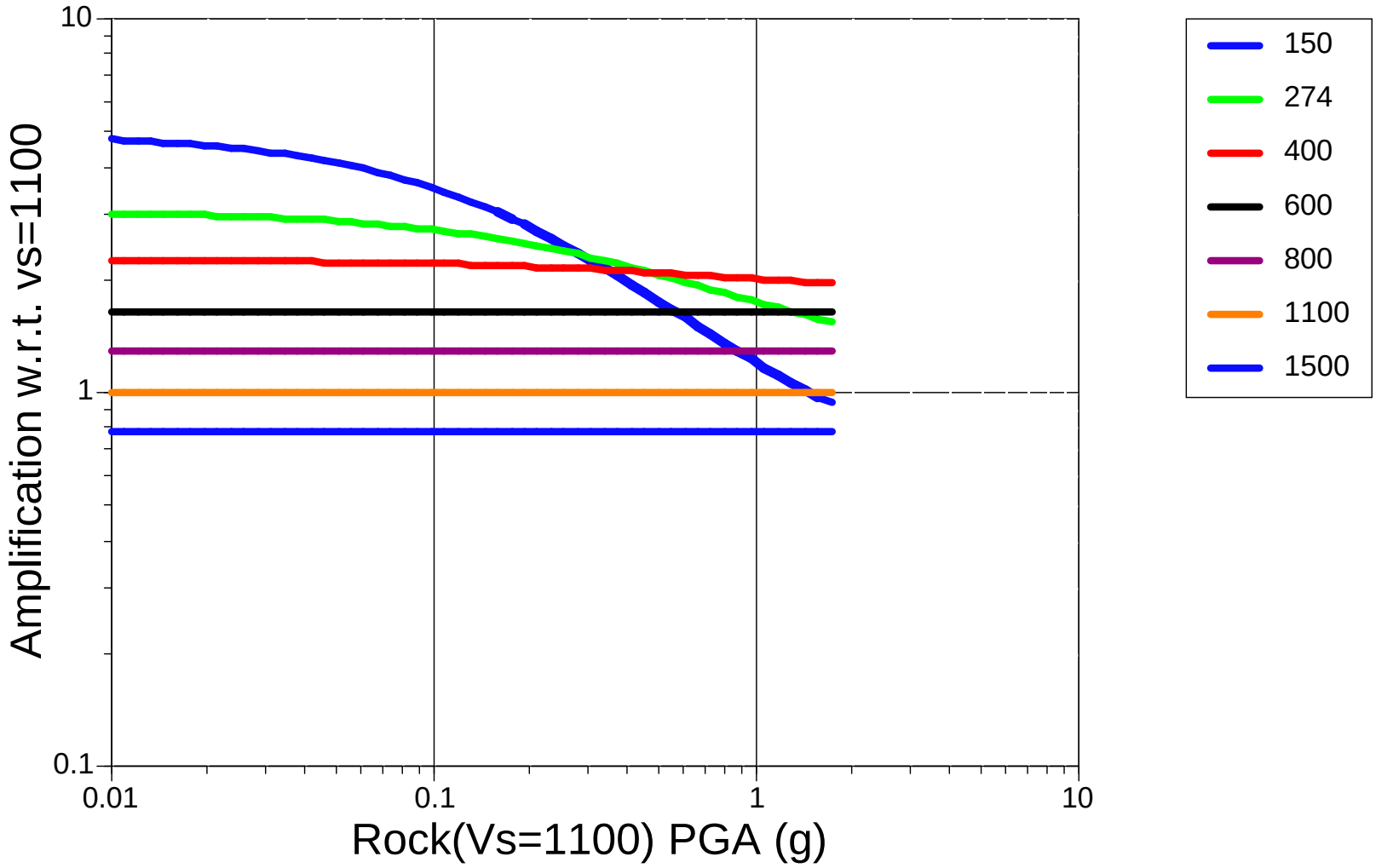
# PGA Amplification from B&A



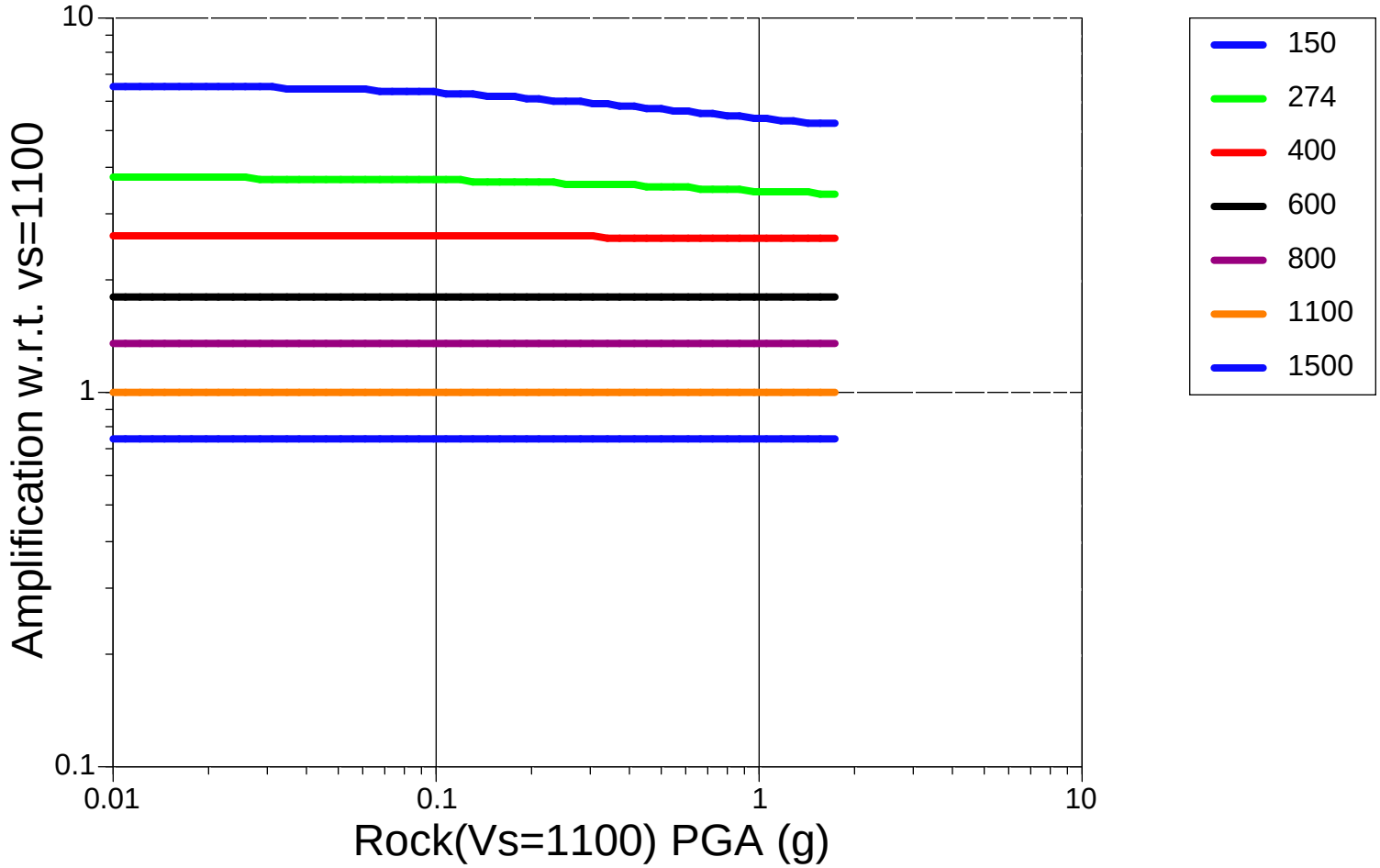
# PGA Amplification



# T=1 Amplification based on Silva Simulations



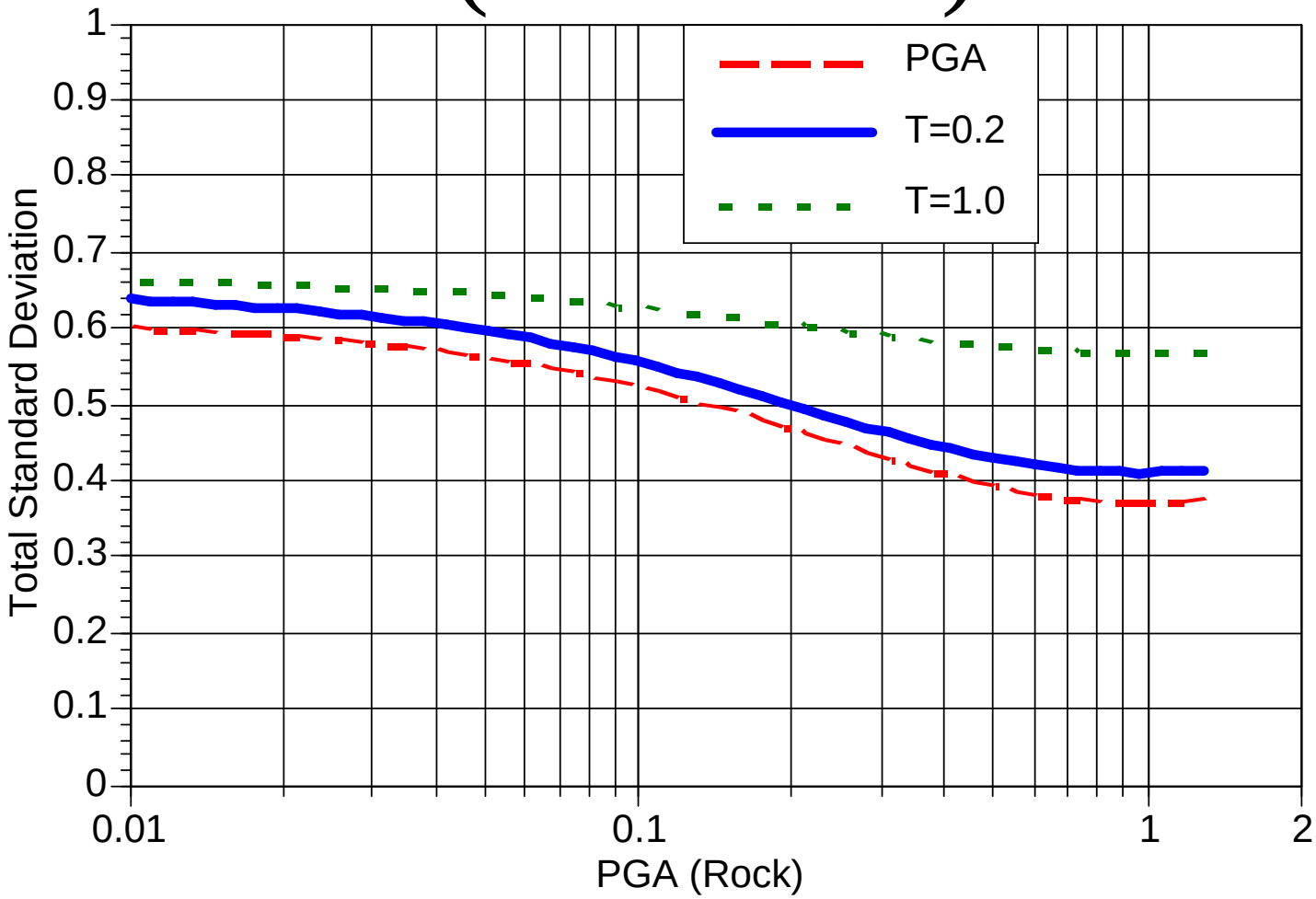
# T=3 Amplification based on $_{T=3.0}$Silva Simulations



# Standard Deviation for Soil Sites

- Earlier NGA Model
  - Used $PGA_{rock}$ + event term for strength of shaking for non-linear soil response
  - Leads to small reduction in soil site sigma
- Modified Model
  - Used $PGA_{rock}$ + full residual for strength of shaking for non-linear soil response
  - Leads to larger reduction in soil site sigma

# Non-linear Effects on Sigma (Vs30=270)



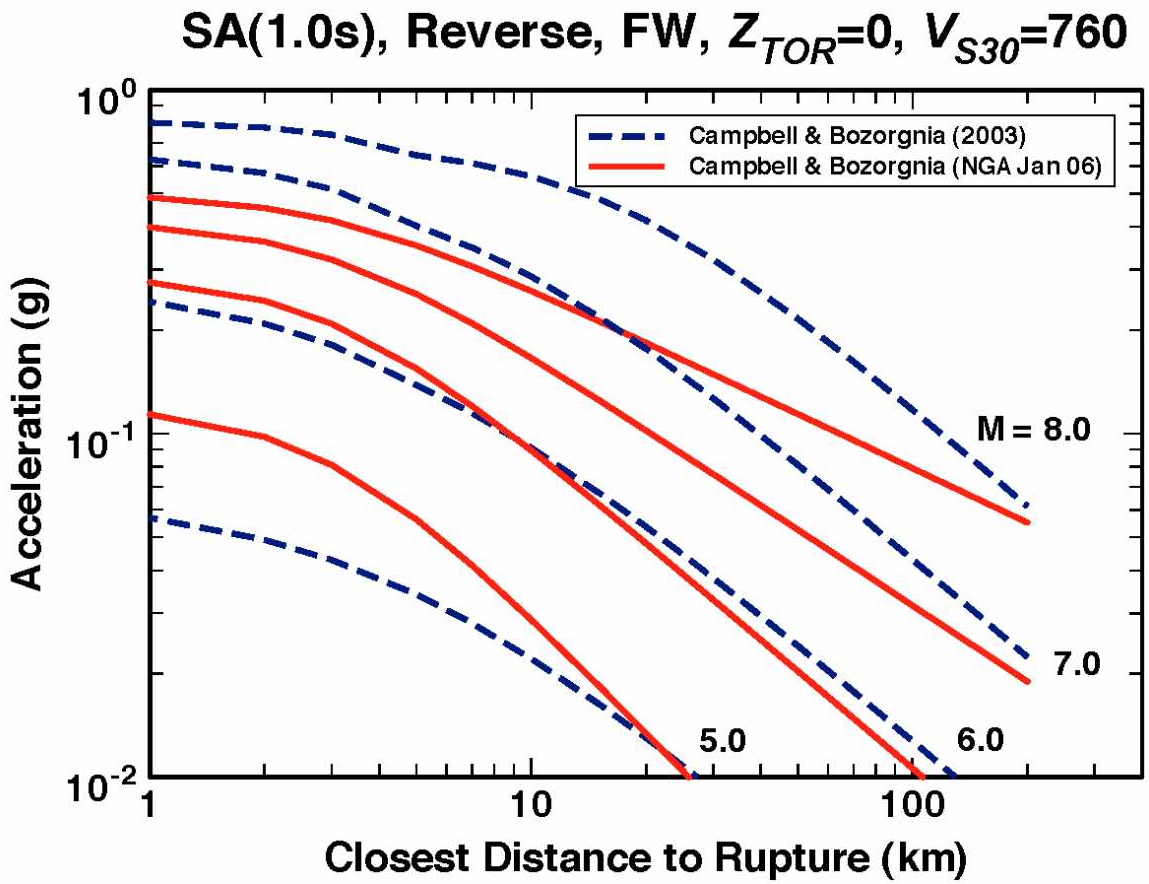
# Style-of-Faulting Factor

- Previous models included larger ground motion for reverse faults
  - Low short period ground motions from Chi-Chi reduces the SOF factor for reverse
    - B&A, A&S have small SOF Factor for reverse
  - C&B only include SOF factor for rev for buried ruptures (35%)
- Normal faulting SOF factor is not well constrained
  - Ranges from 0 to 20% reduction as compared to SS

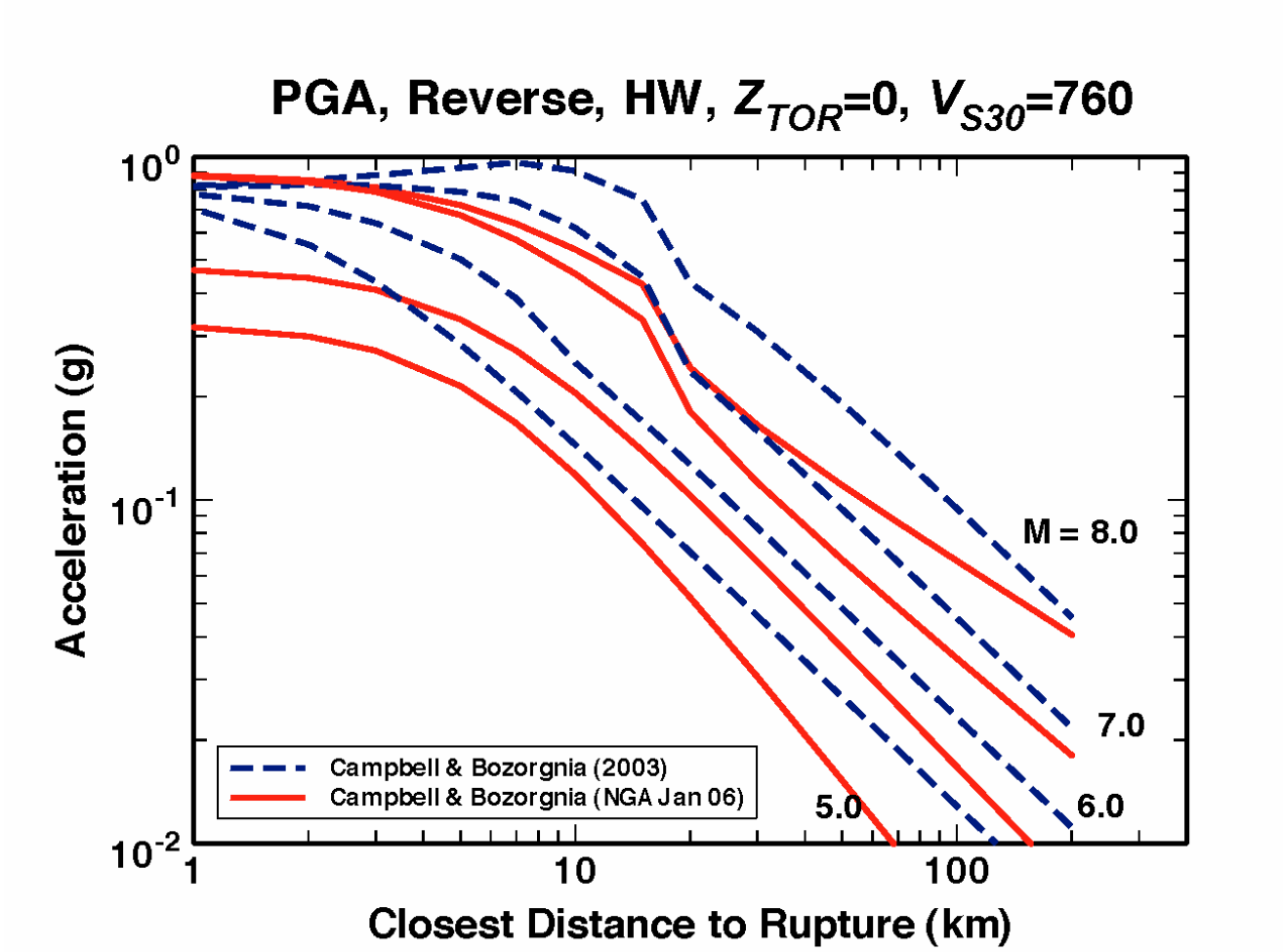
# Hanging wall and Footwall factors

- Large differences in NGA models due to approach used for HW and FW
- HW/FW effects dominated by Chi-Chi
- Use of Rjb and Rrup to simplify definition of HW
  - (Rrup - Rjb)/Rrup  for Rjb>0
  - Issue of discontinuity if faulting reaches the surface
    - Tapers as function of depth of top of rupture

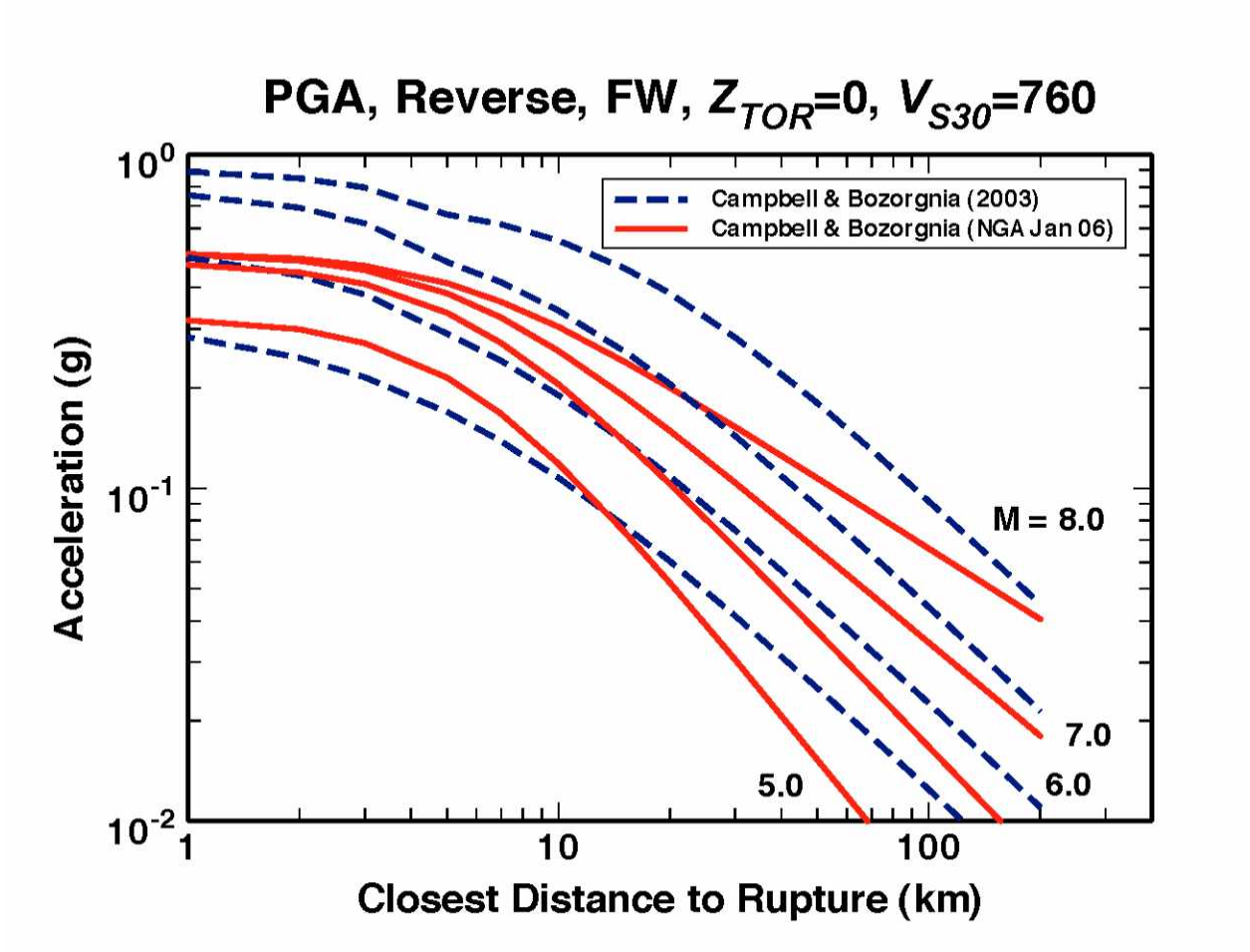
# Campbell & Bozorgnia FW, T=1



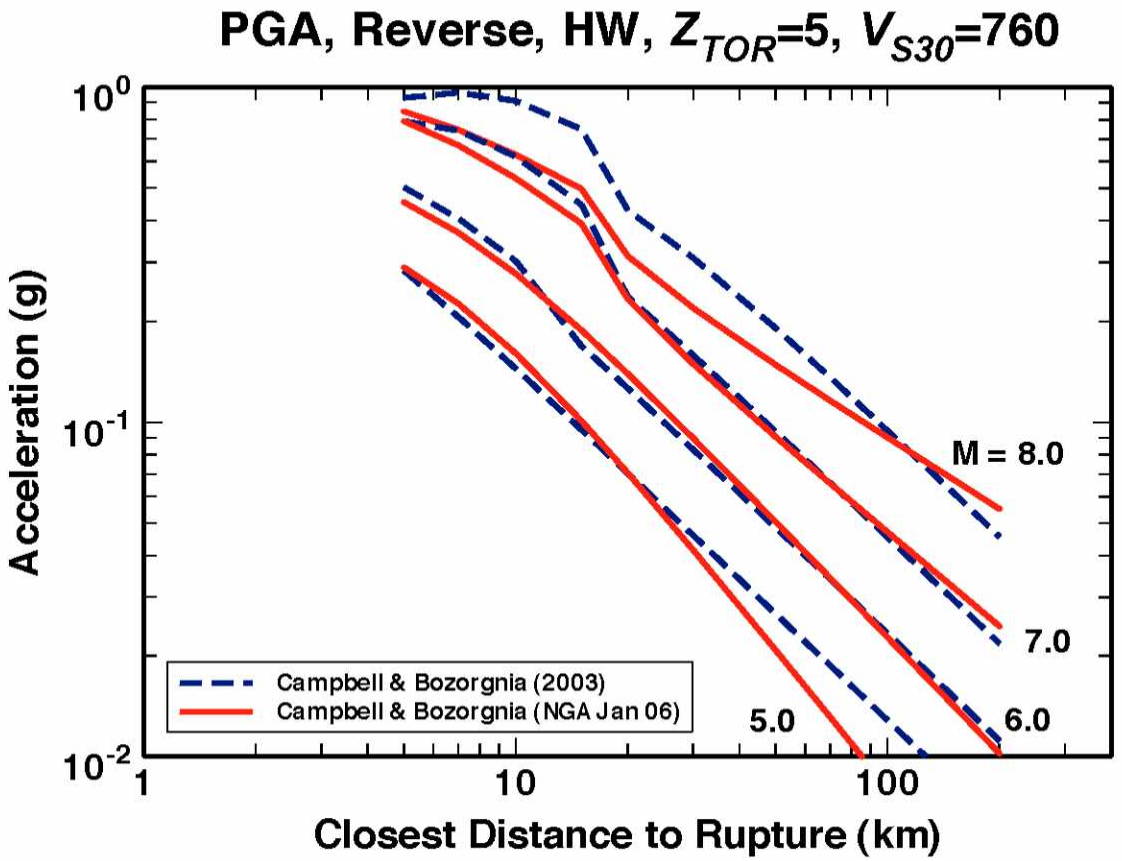
# Campbell & Bozorgnia HW, PGA



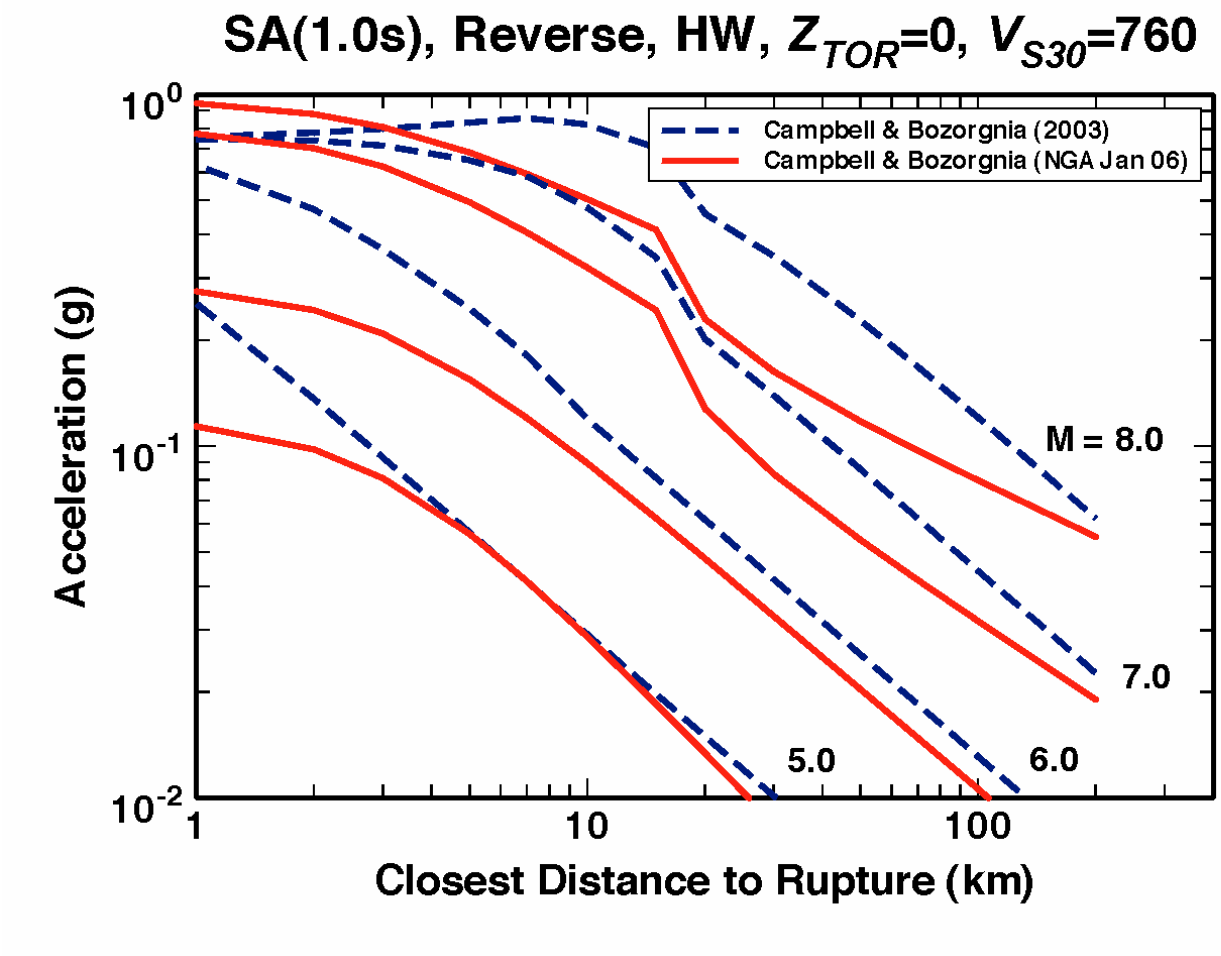
# Campbell & Bozorgnia FW, PGA



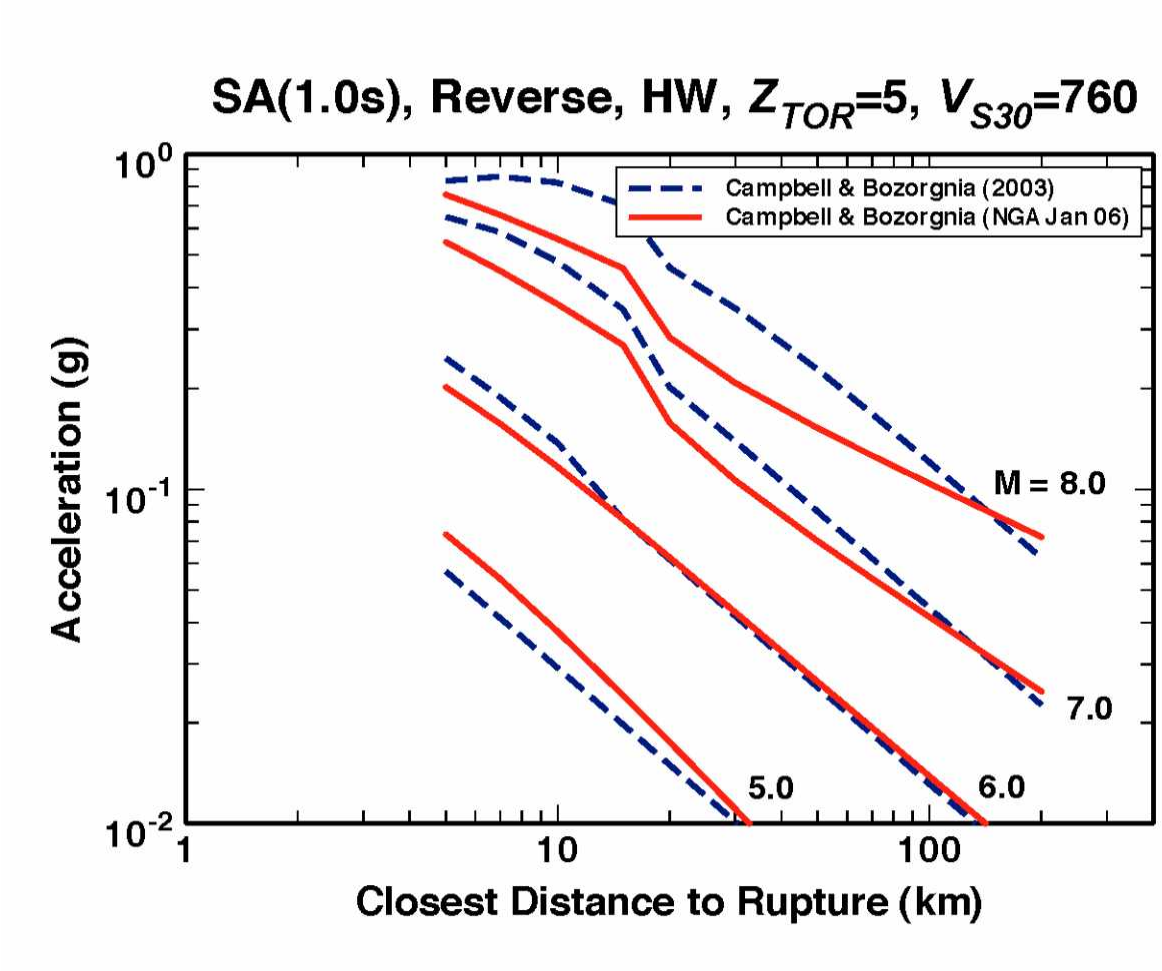
# Campbell & Bozorgnia HW, PGA, buried



# Campbell & Bozorgnia HW. T=1



# Campbell & Bozorgnia HW, T=1, Buried



# Additional Parameters

- Aspect Ratio
  - A&S
- Buried reverse
  - C&B
- Top of rupture
  - A&S, C&B, C&Y
- Footwall
  - C&Y
- Depth of soil (Z1.0, Z2.5)
  - A&S (Z1.0) - based on analytical models
  - C&B (Z1.0, Z2.5)
  - C&Y (Z1.0)

# Are the Models Too Complicated?

- These models have more parameters than previous empirical models
  - Some parameters are difficult to determine
  - Some parameters may be inconsistent between source characterization and GM data set

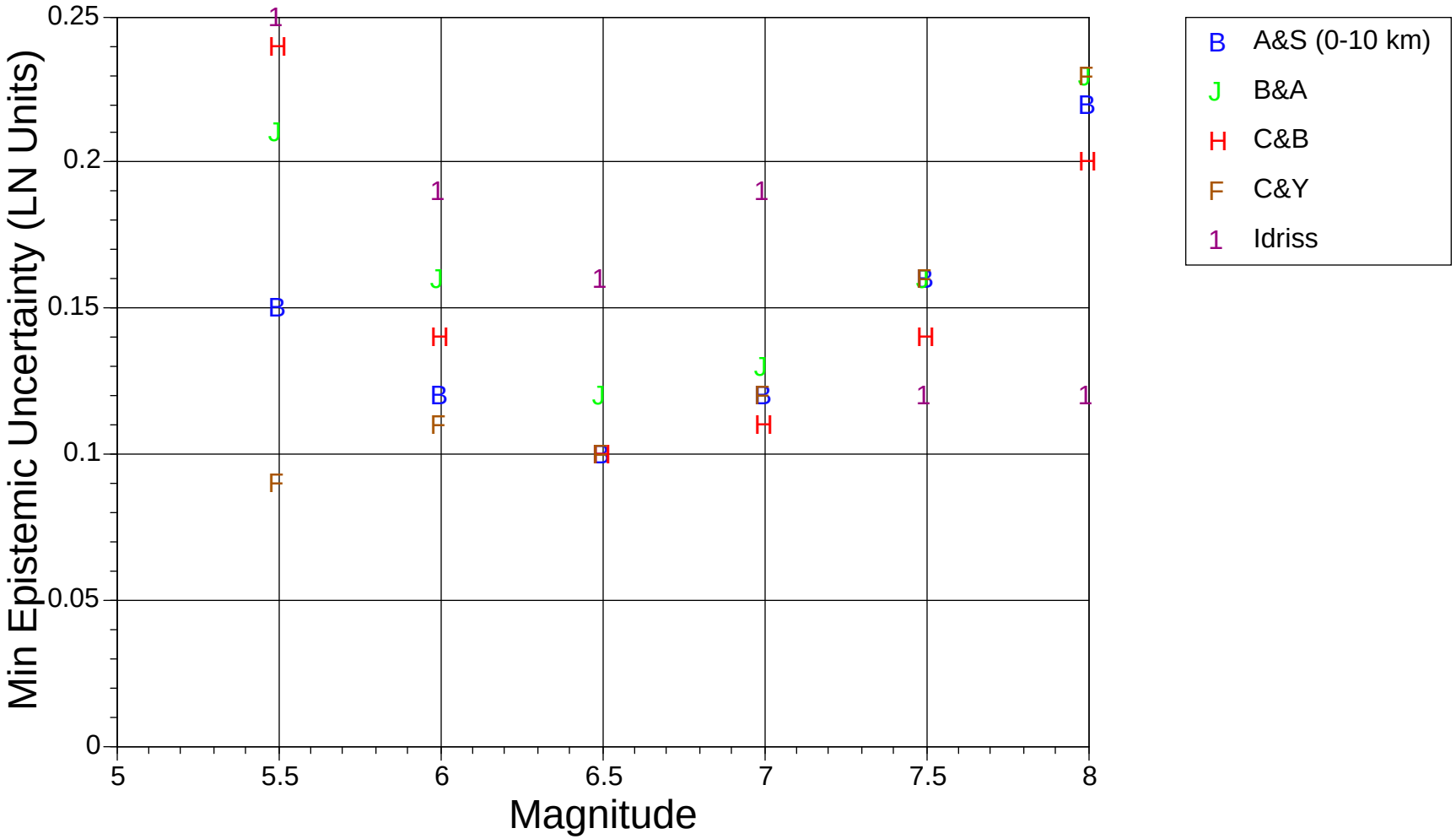
# Summary of NGA model Changes from Previous Models

- Decrease in median on rock (Vs=760), particularly at large magnitudes
- Increase in the sigma for large magnitudes, decrease in sigma for small magnitudes (M<6)
  - At high GM levels, sigma is smaller for soil than for rock sites due to non-linearity
- SOF factor more complicated, not just reverse vs strike-slip
- HW included in most models, (JB distance implicitly includes HW)
- Models applicable (controlled extrapolation) out to 200 km and for M up to 8.5 SS

# Epistemic Uncertainty

- ALL:
  - NGA models from five developers should not be considered a measure of epistemic uncertainty
    - Consider data set size, and range from simulations
    - Epistemic uncertainty in median from data set size is about 25% for close in stations
- A&S:
  - Looking at effect of removing events
- C&Y:
  - Looking at effect of constraining coefficients

# Epistemic due to Data Set Size
# 0-10 km



# Potential Bias in NGA Models

- Use of Foreign Data
  - Chi-Chi, Kocaeli, Duzce
  - Are these data applicable to WUS?
- Are data from large recent earthquakes biased?
  - Were the locations of strong motion recorders in lower than average regions?
    - Chi-Chi: more footwall stations, more stations to the south
    - Denali: PS10 located near a lower than average part of the slip distribution

# Issues for inclusion of NGA models in national maps?

- Major update of all major models used in CA
  - Typically, not all models are updated at once
  - This gives some damping to the changes to the maps
- NGA developers consider the new models to be improvements over previous models
  - Previous models had much smaller data sets and not as much review of the parameters in the data set
  - Working together has provided checks along the way
  - Key: NGA developers consider the foreign mainshock data to be applicable to CA
- Should previous models be maintained in the national map with some weighting to dampen the adjustments?
- Will the models be done in time?

# Schedule (w/o directivity)

- Currently comparing models
  - Previous comparisons focused on SS and rock
- Now focus on SOF and HW/FW
- Complete comparisons (April)
- NGA models will be presented at EERI/SSA mtg
- Final models sent to USGS no later than end of May
- Public release of coefficients when reports for at three models are ready

# Directivity Effect

- Will add this effect after base model is released
- Will likely use a more complicated parameterization that includes the radiation pattern
- Will develop a simplified approach that modifies the sigma to account for directivity
  - This will be useful for hazard maps
- Schedule: Start in June, complete by Dec
  - Paul Spudich has been working on this