Ground-Motion Attenuation Relationships for Cascadia Subduction Zone Megathrust Earthquakes Based on a Stochastic Finite-Fault Model

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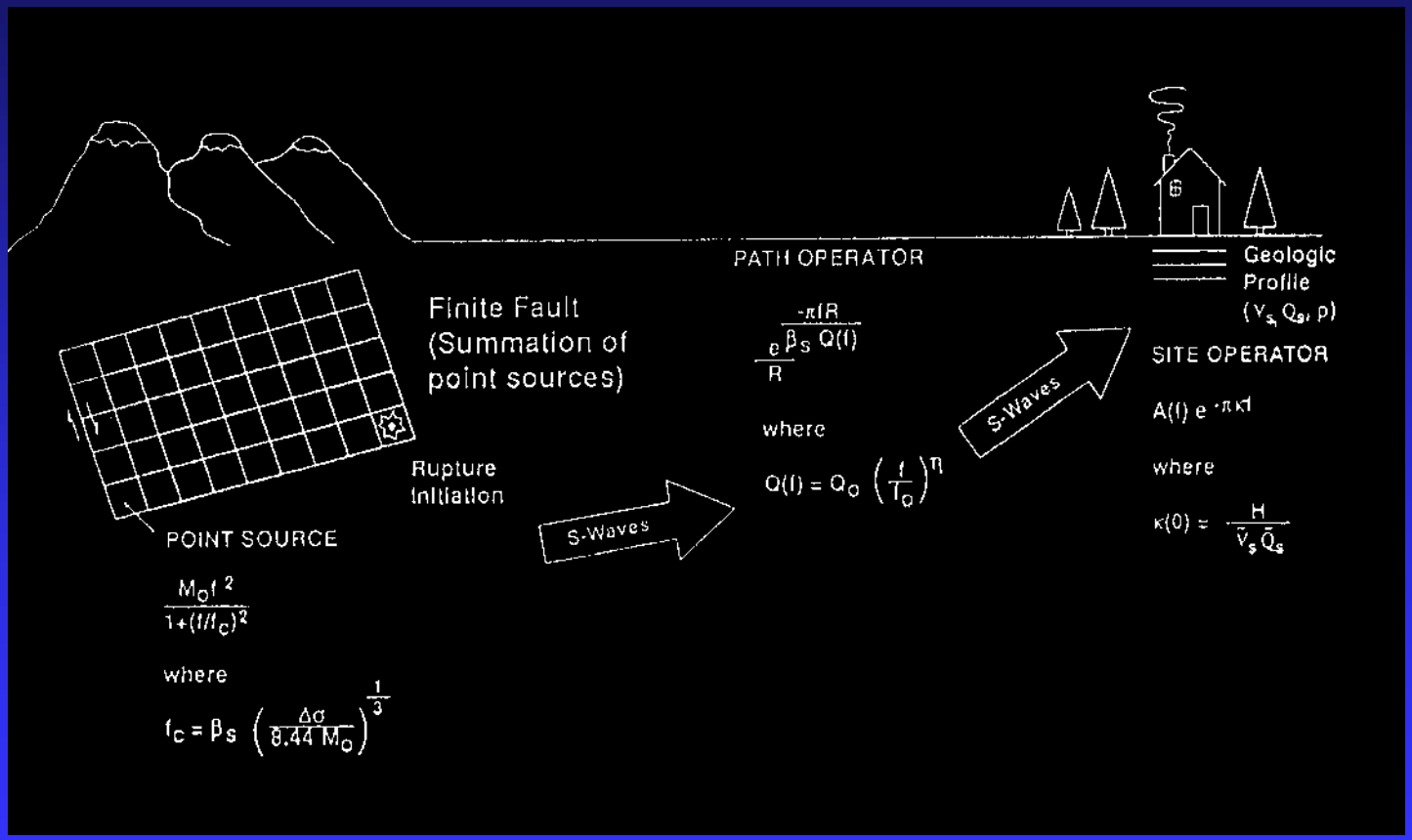
Pacific Northwest Workshop for USGS Hazard Maps

Seattle Washington, March 28-29, 2006

Outline

- Stochastic Finite-Fault Model
- Model Validation
- Rock and Soil Profiles
- Ground Motion Comparisons
- Model Updates

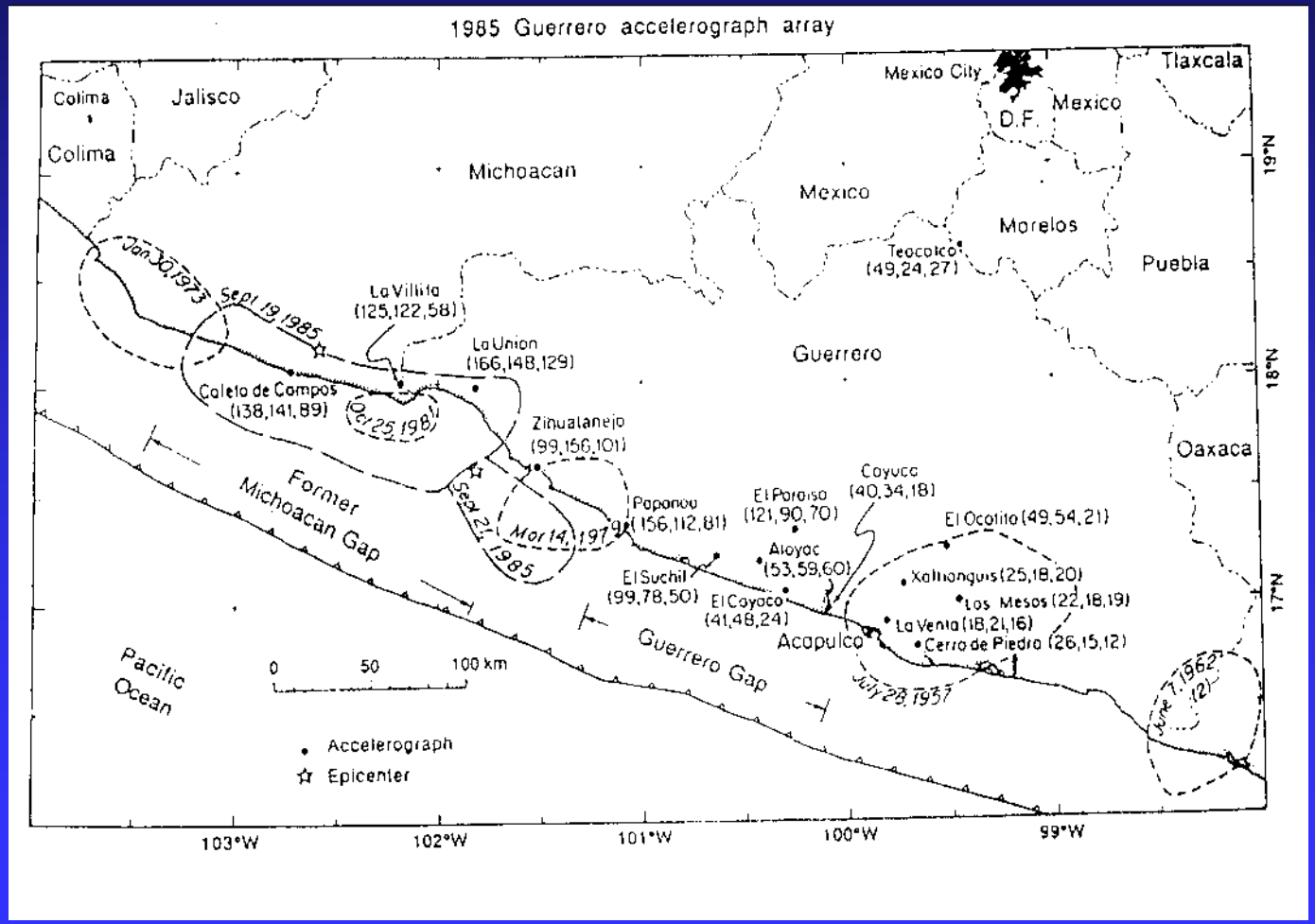
Stochastic Finite-Fault Model

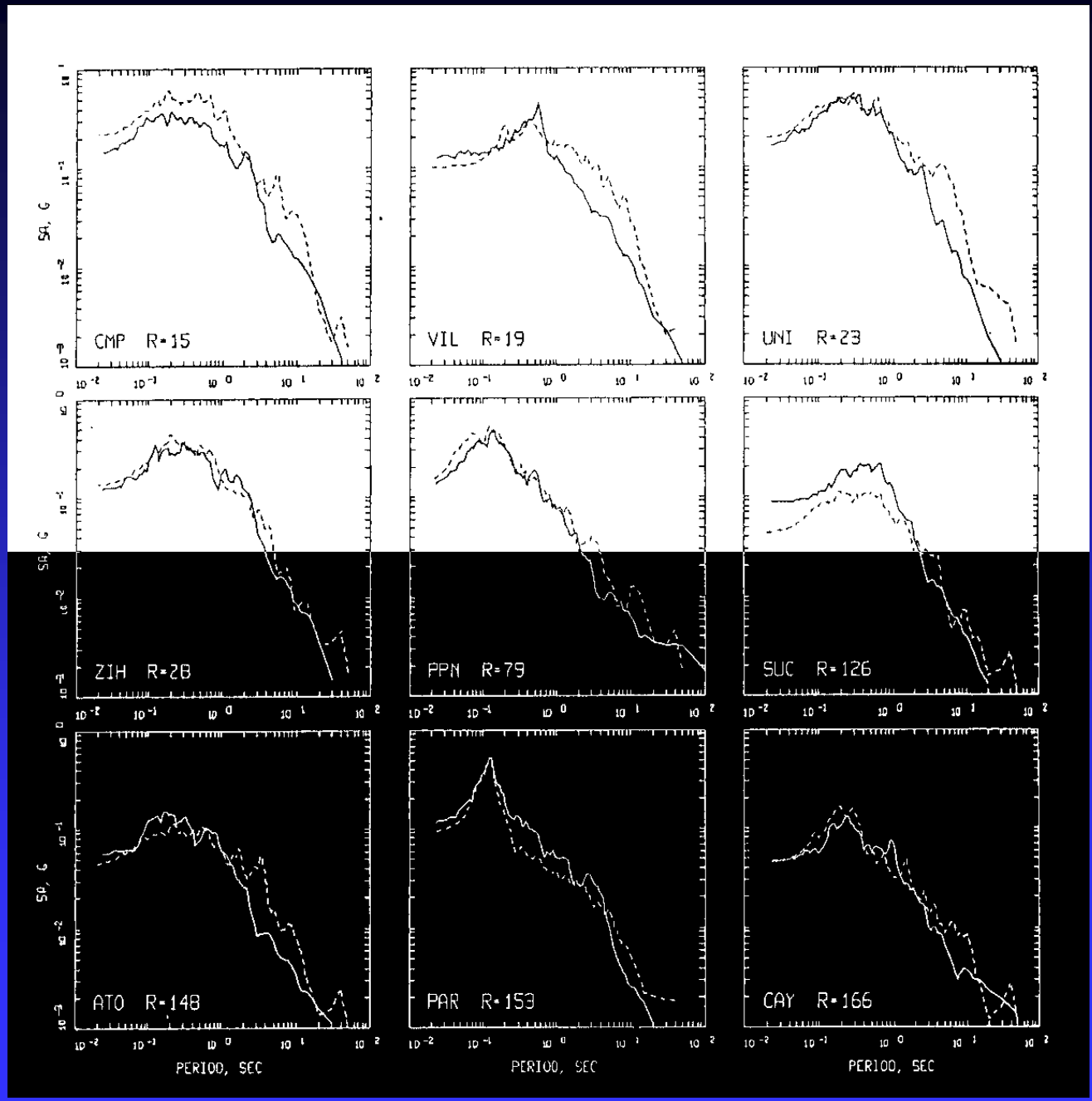


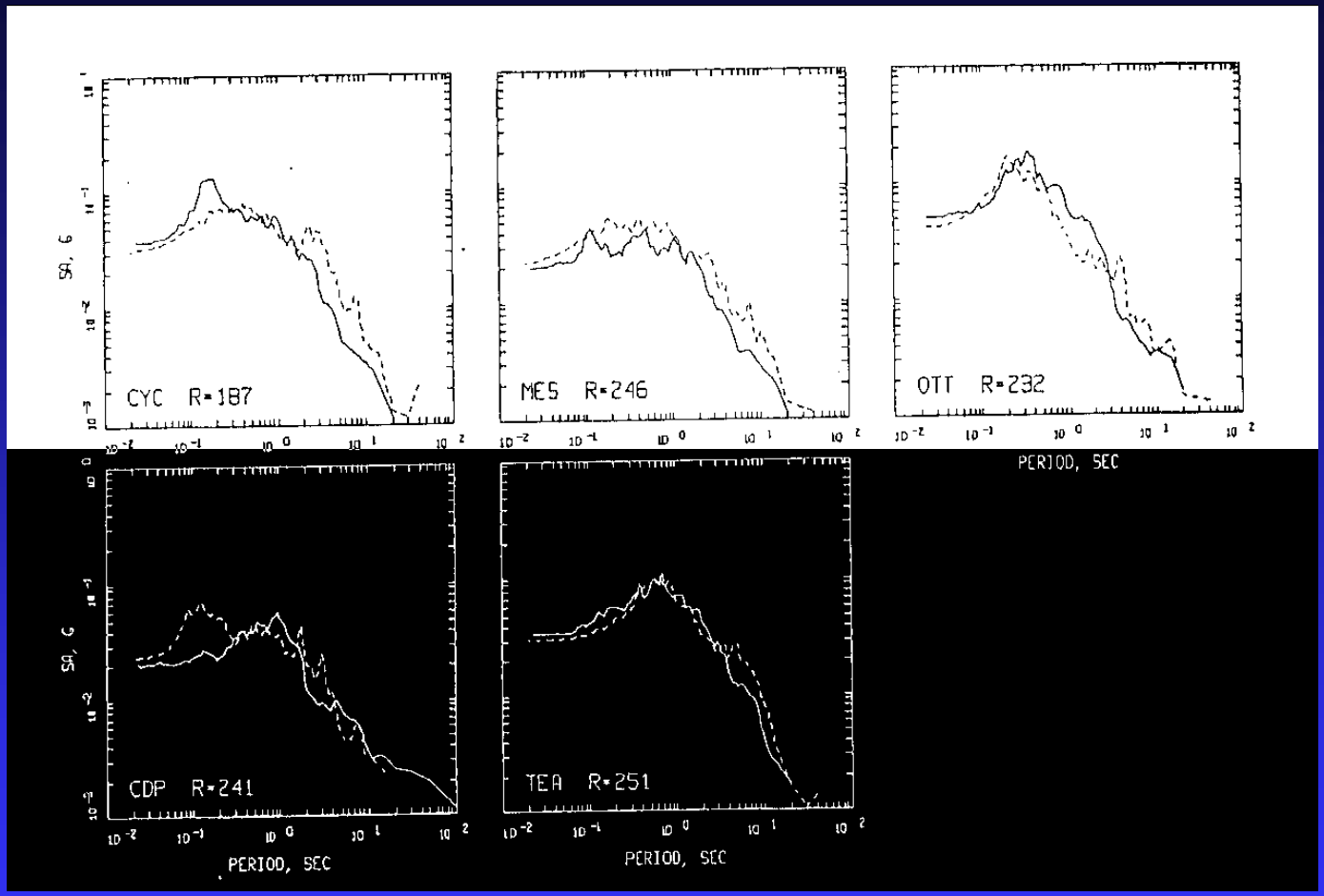
Model Validation

- 1985 Michoacan, Mexico Earthquake (M8.0):
  - 14 rock sites
  - Distances 15 - 251 km
- 1985 Valpariso, Chile Earthquake (M7.9):
  - 6 rock sites
  - Distances 39 - 119 km

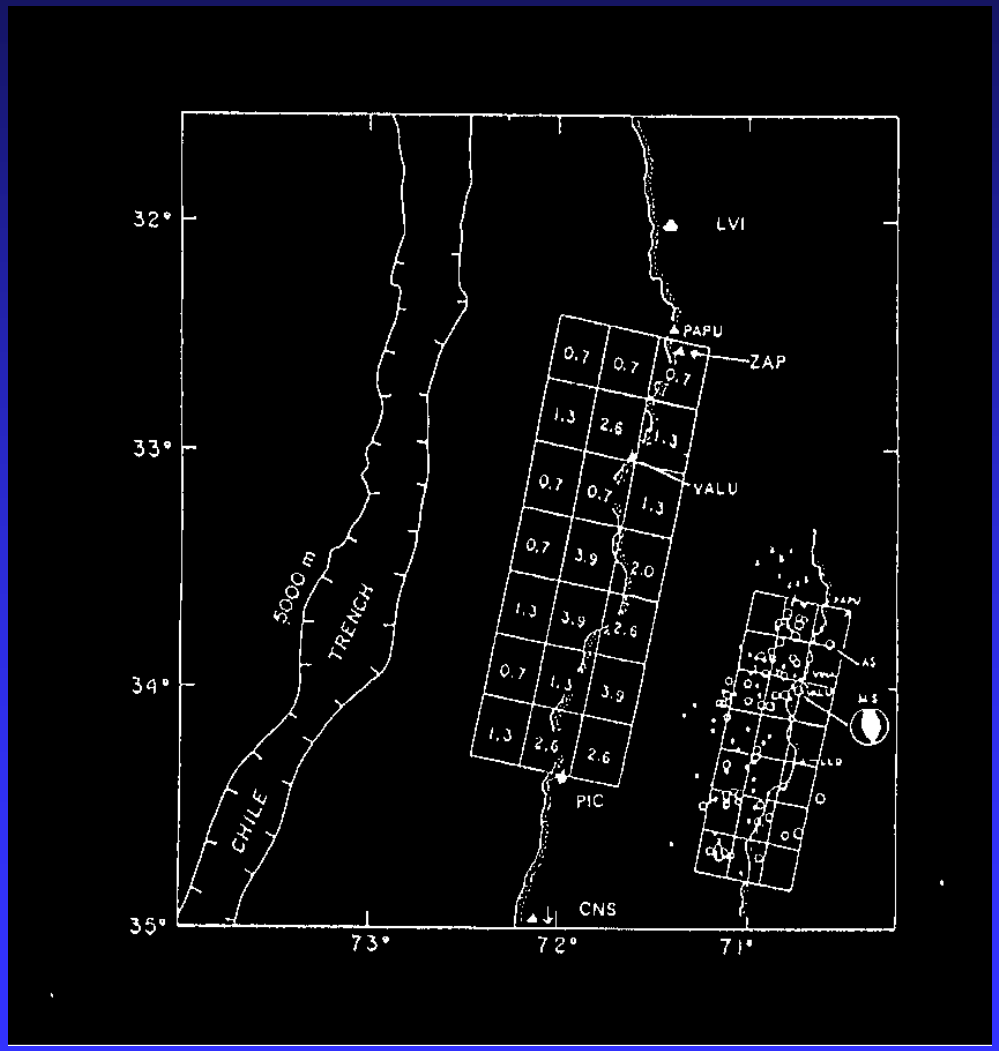
Michoacan Earthquake

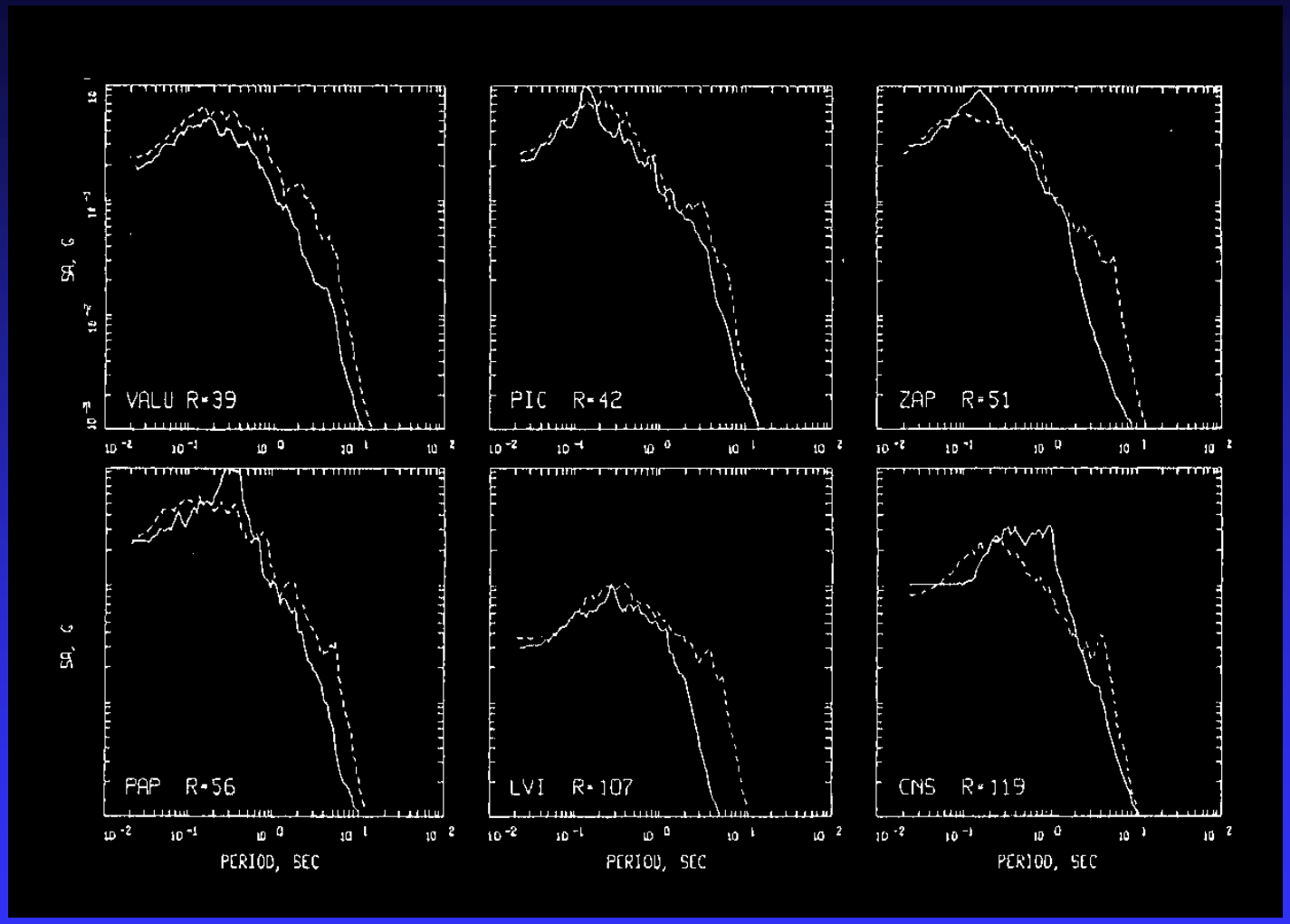



CMP R=15
VIL R=19
UNI R=23
ZIH R=28
PPN R=79
SUC R=126
ATO R=148
PAR R=153
CAY R=166
PERIOD, SEC
PERIOD, SEC
PERIOD, SEC

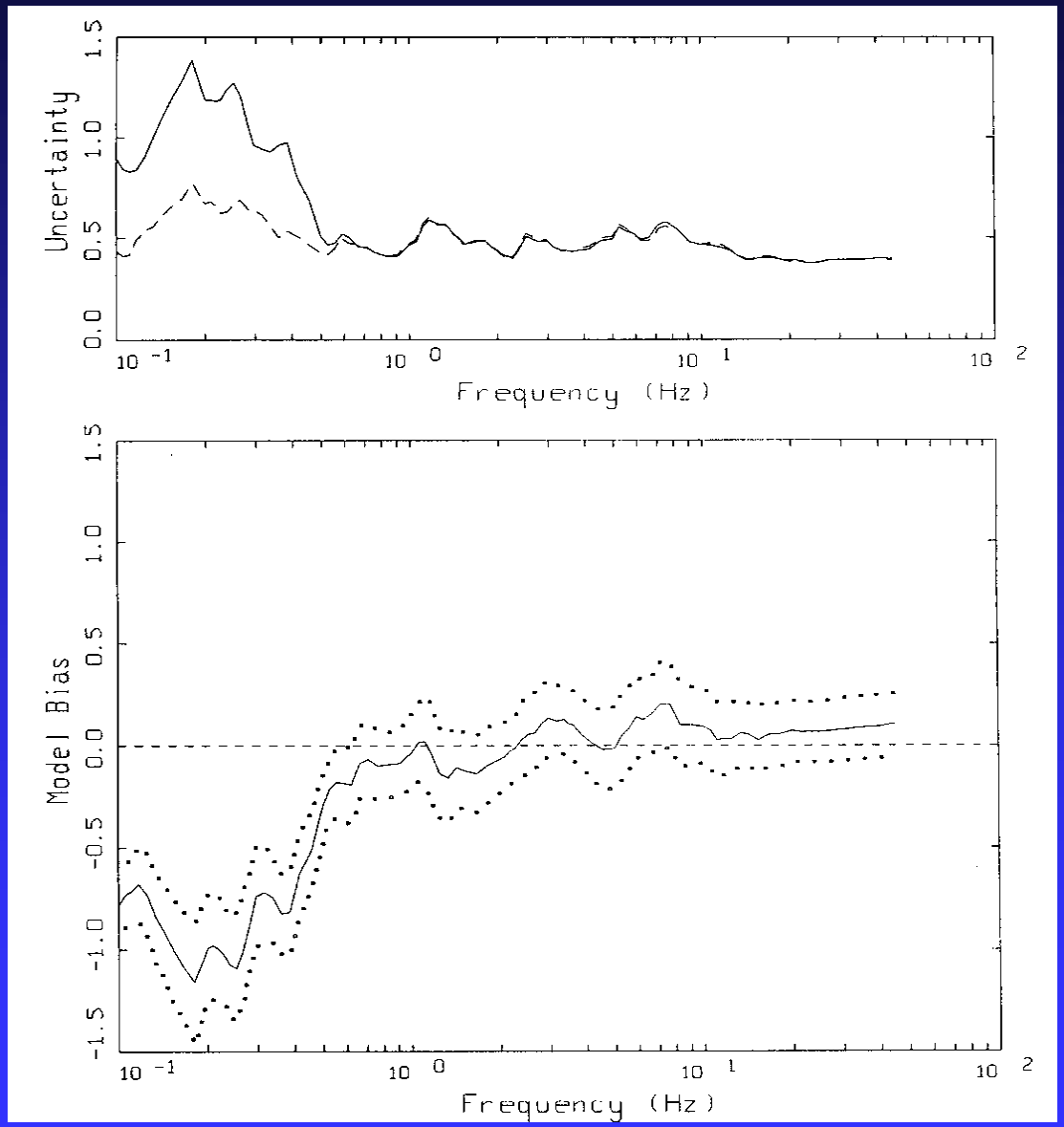

CYC R=187
MES R=246
OTT R=232
CDP R=241
TEA R=251
SA, G
PERIOD, SEC

Valpariso Earthquake



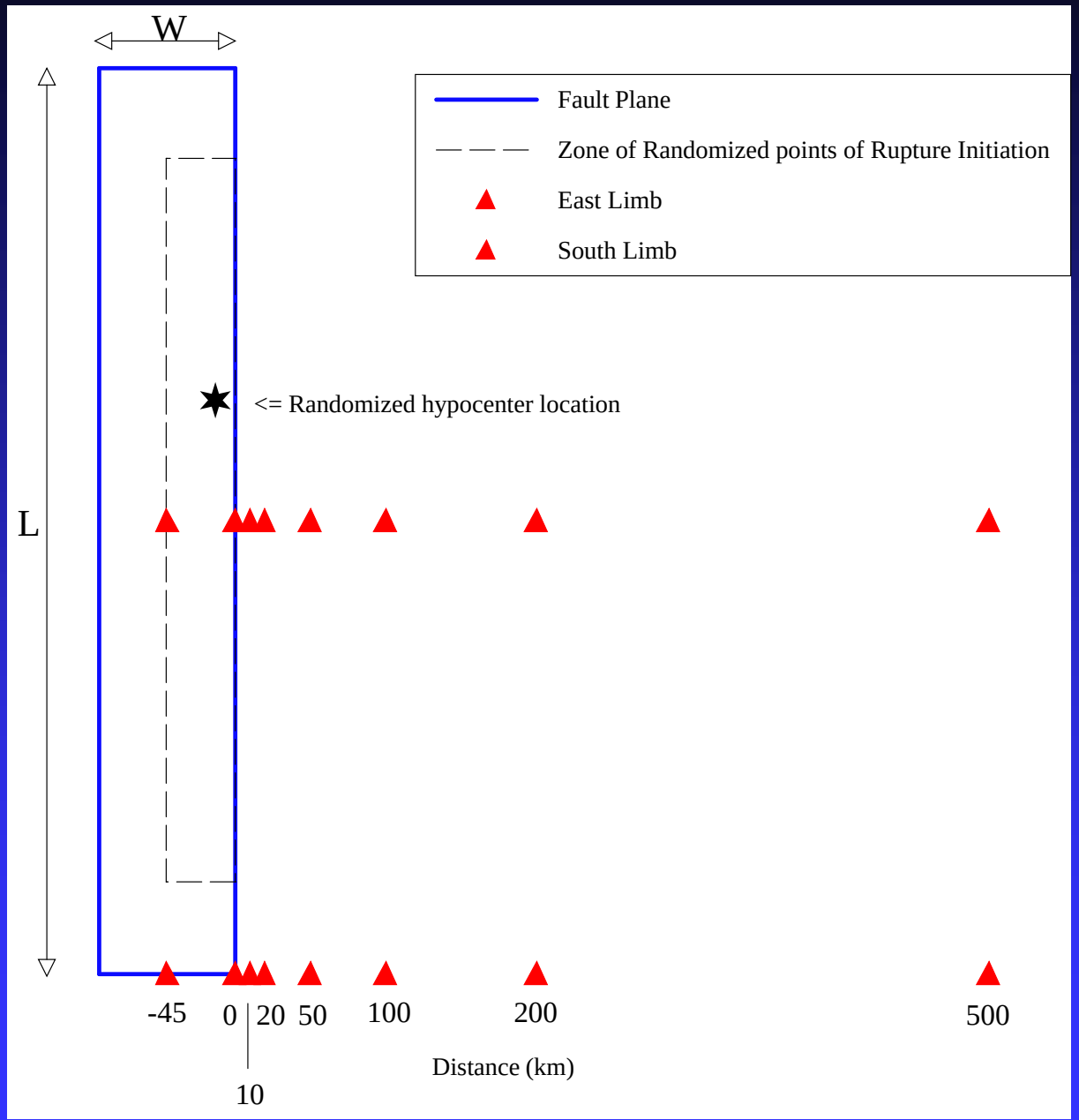

VALU R=39
PIC R=42
ZAP R=51
PAP R=56
LVI R=107
CNS R=119
PERIOD, SEC
PERIOD, SEC
PERIOD, SEC

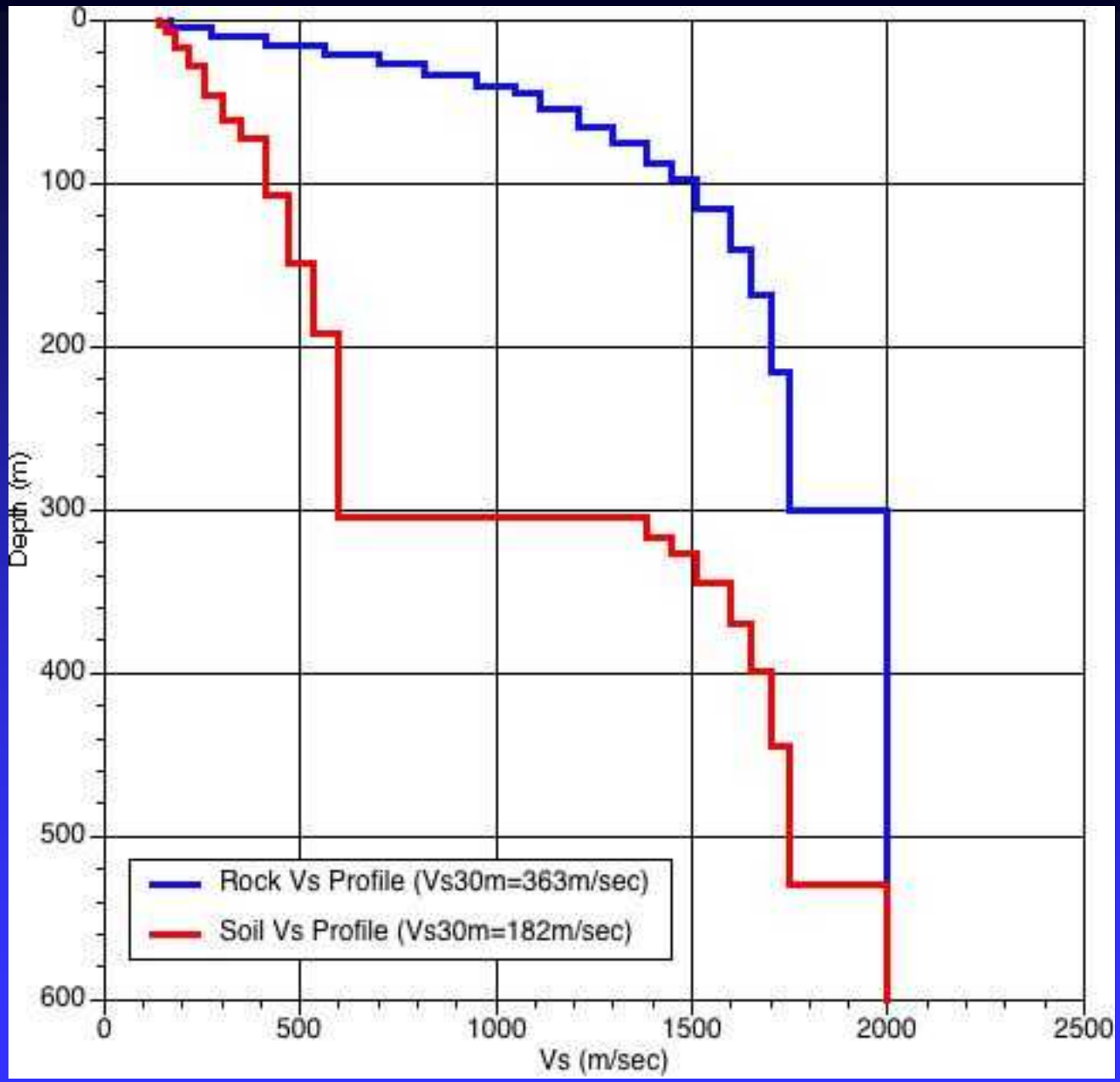
Modeling Bias

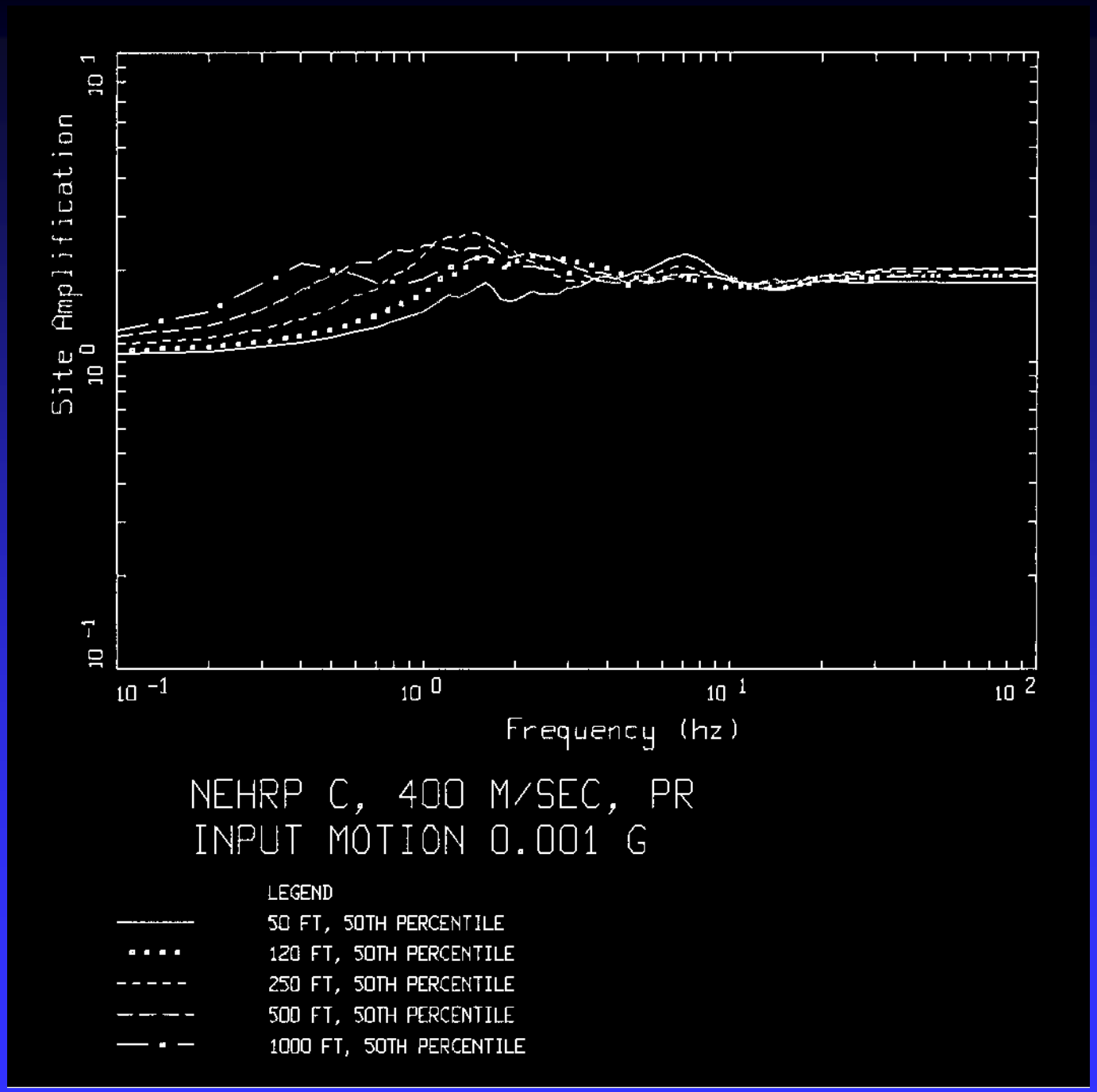


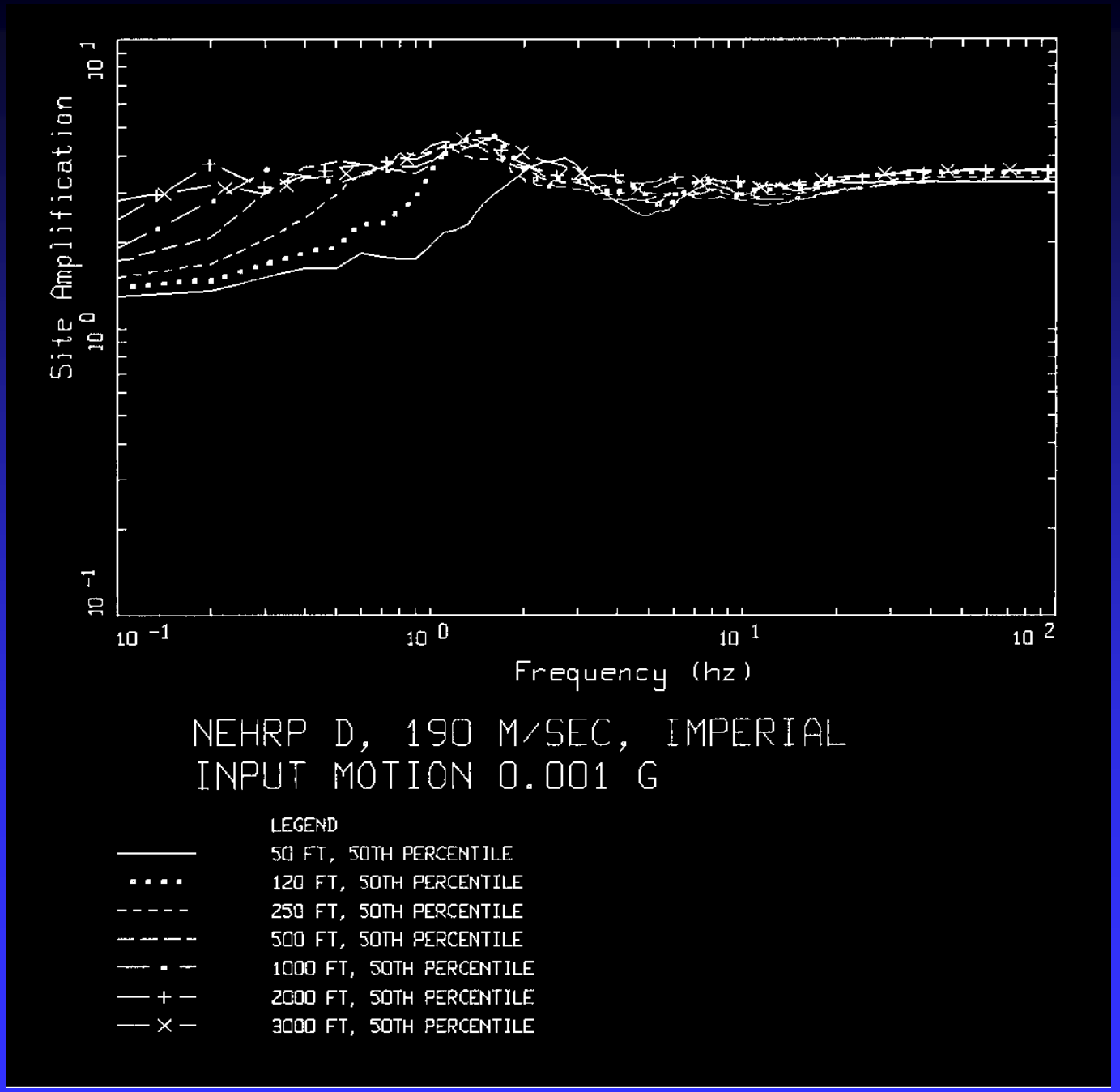
Cascadia Finite-Fault Model

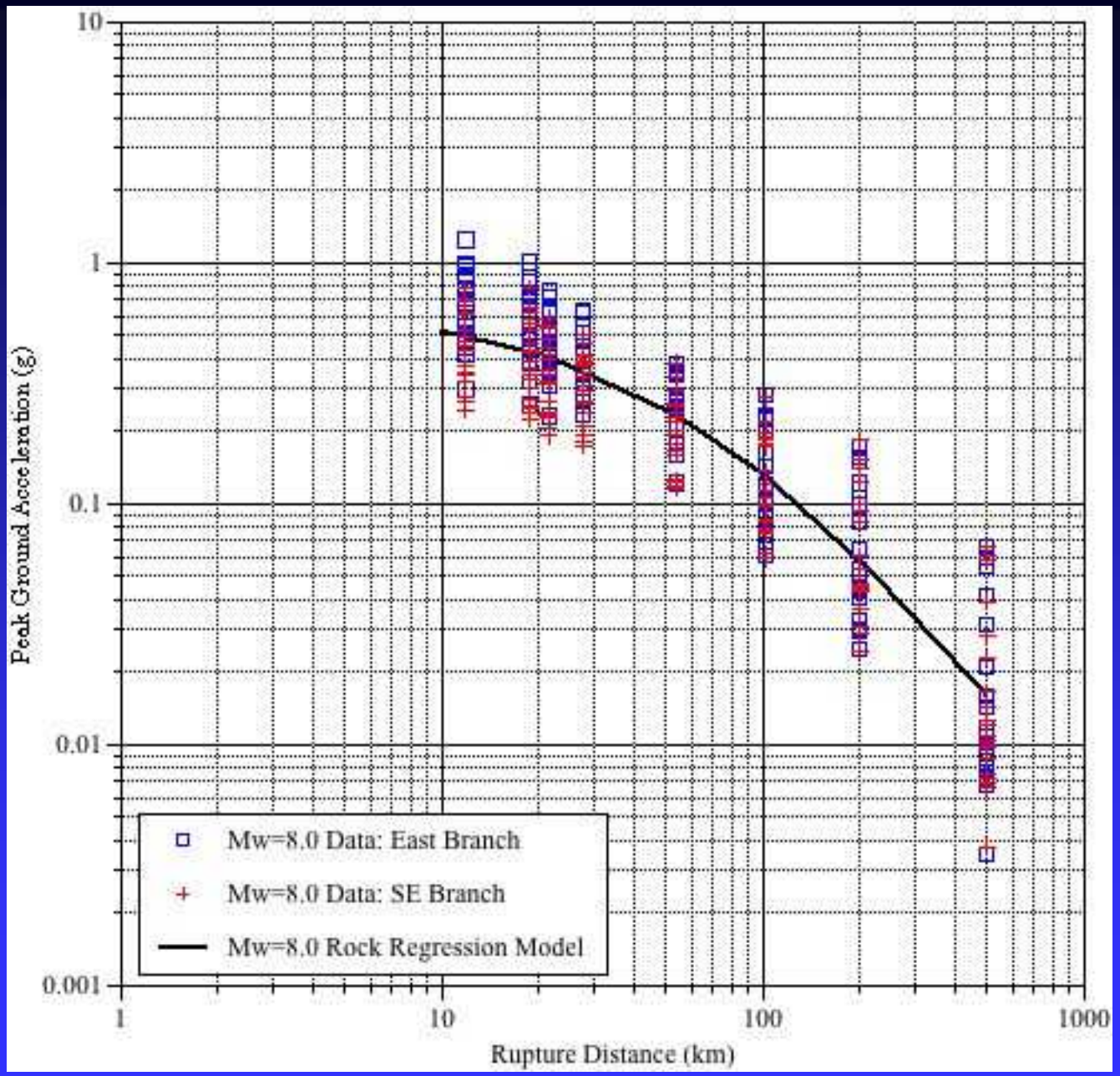
- M 8.0, 8.5, 9.0
- Fault lengths = 150, 450, and 1,100 km
- Fault Width = 90 km
- Dip Angle = 9^{o}
- 16 Site Locations (Center limb, South limb)
- Rock (Columbia River Basalt), Soil site Conditions
- $Q(f) = 380f^{0.39}$ (Atkinson, 1995)
- Crustal Model (Trehu et al., 1994; Cohee et al., 1991; Ludwin et al., 1991)

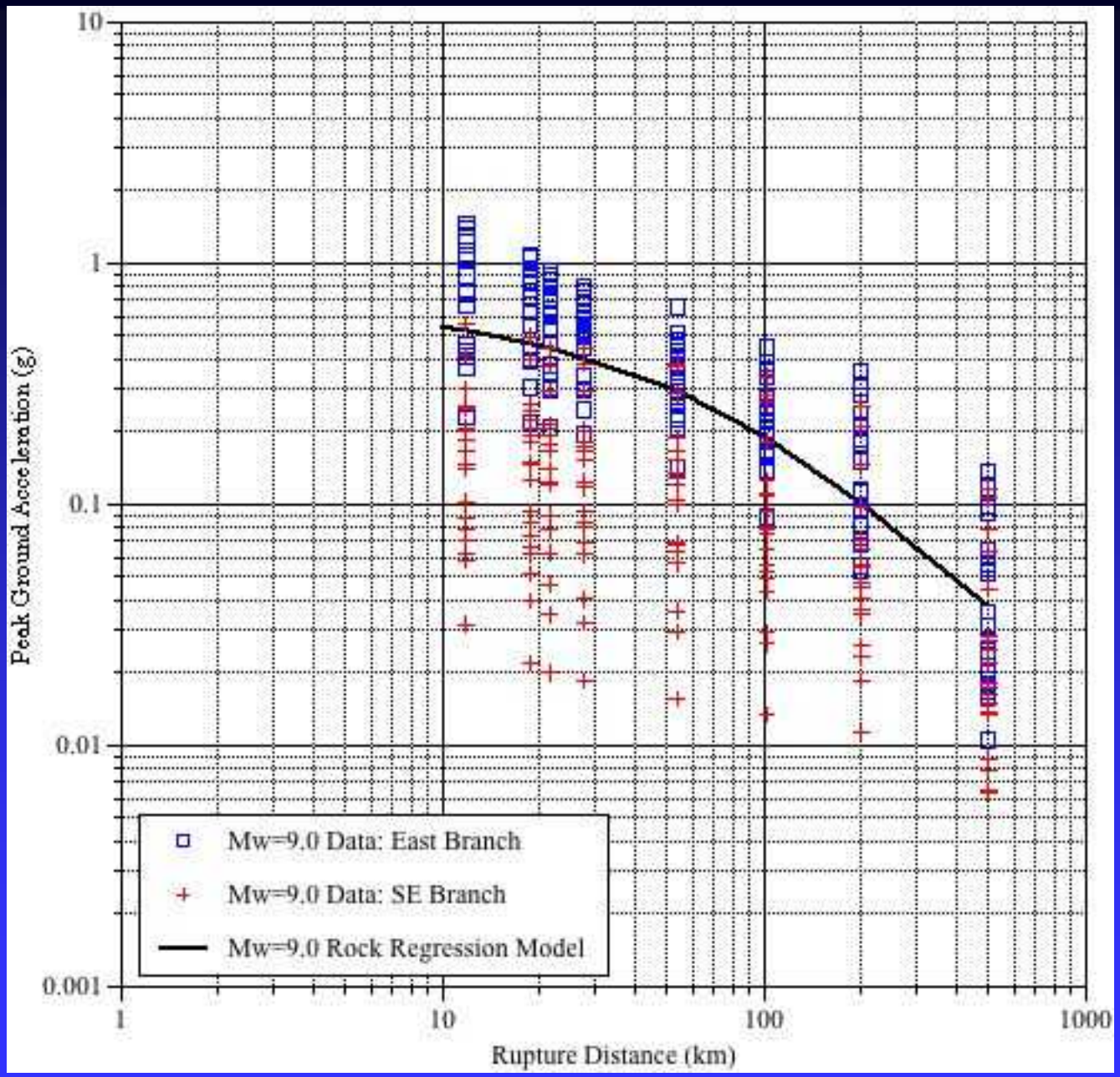

W
L
Fault Plane
Zone of Randomized points of Rupture Initiation
East Limb
South Limb
<= Randomized hypocenter location
-45
0
20
50
100
200
500
10
Distance (km)

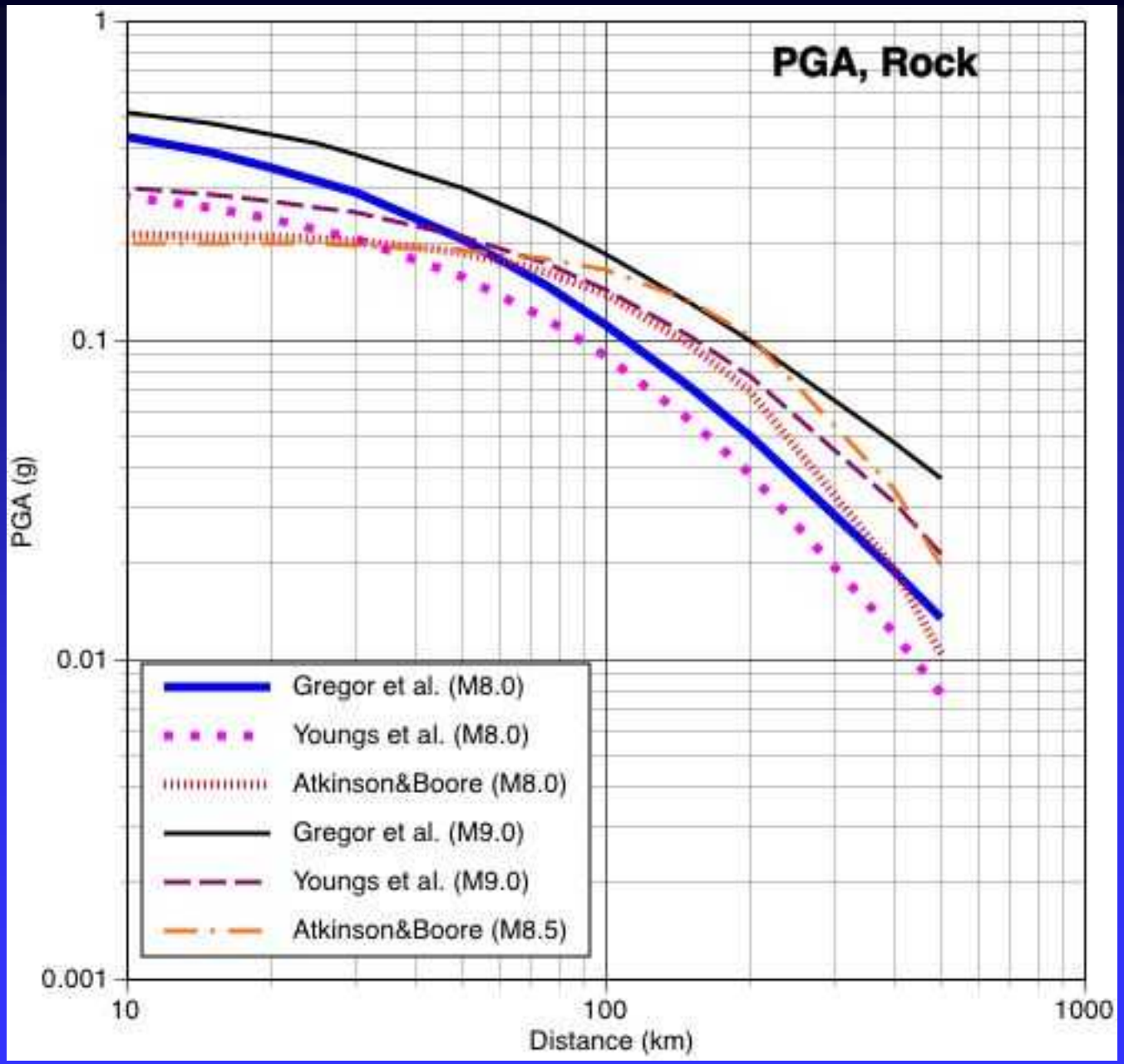

0
100
200
300
400
500
600
Depth (m)
0
500
1000
1500
2000
2500
Vs (m/sec)
Rock Vs Profile (Vs30m=363m/sec)
Soil Vs Profile (Vs30m=182m/sec)

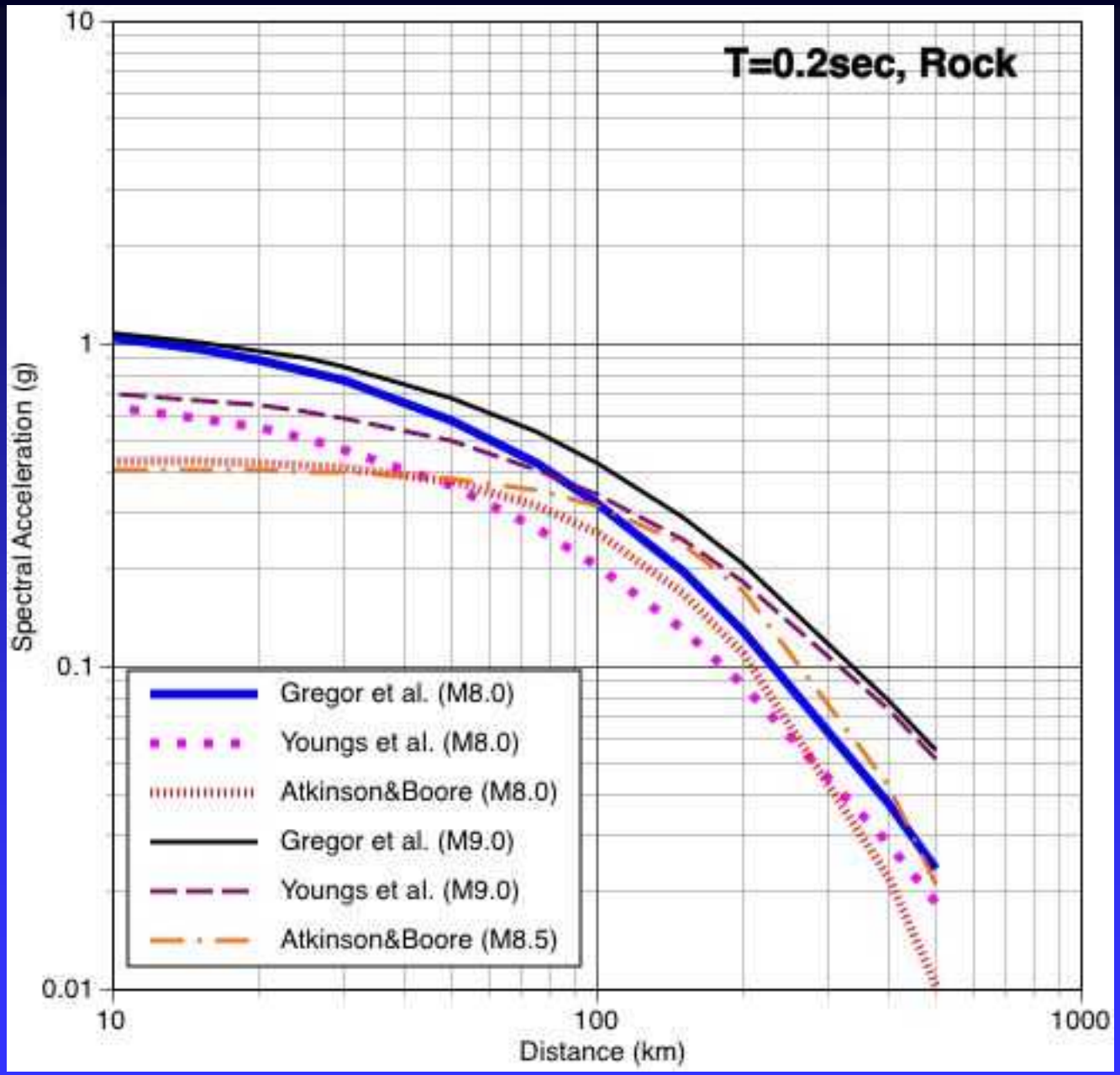

Site Amplification
10 1
10 0
10 -1
10 -1
10 0
10 1
10 2
Frequency (hz)
NEHRP C, 400 M/SEC, PR
INPUT MOTION 0.001 G
LEGEND
50 FT, 50TH PERCENTILE
120 FT, 50TH PERCENTILE
250 FT, 50TH PERCENTILE
500 FT, 50TH PERCENTILE
1000 FT, 50TH PERCENTILE

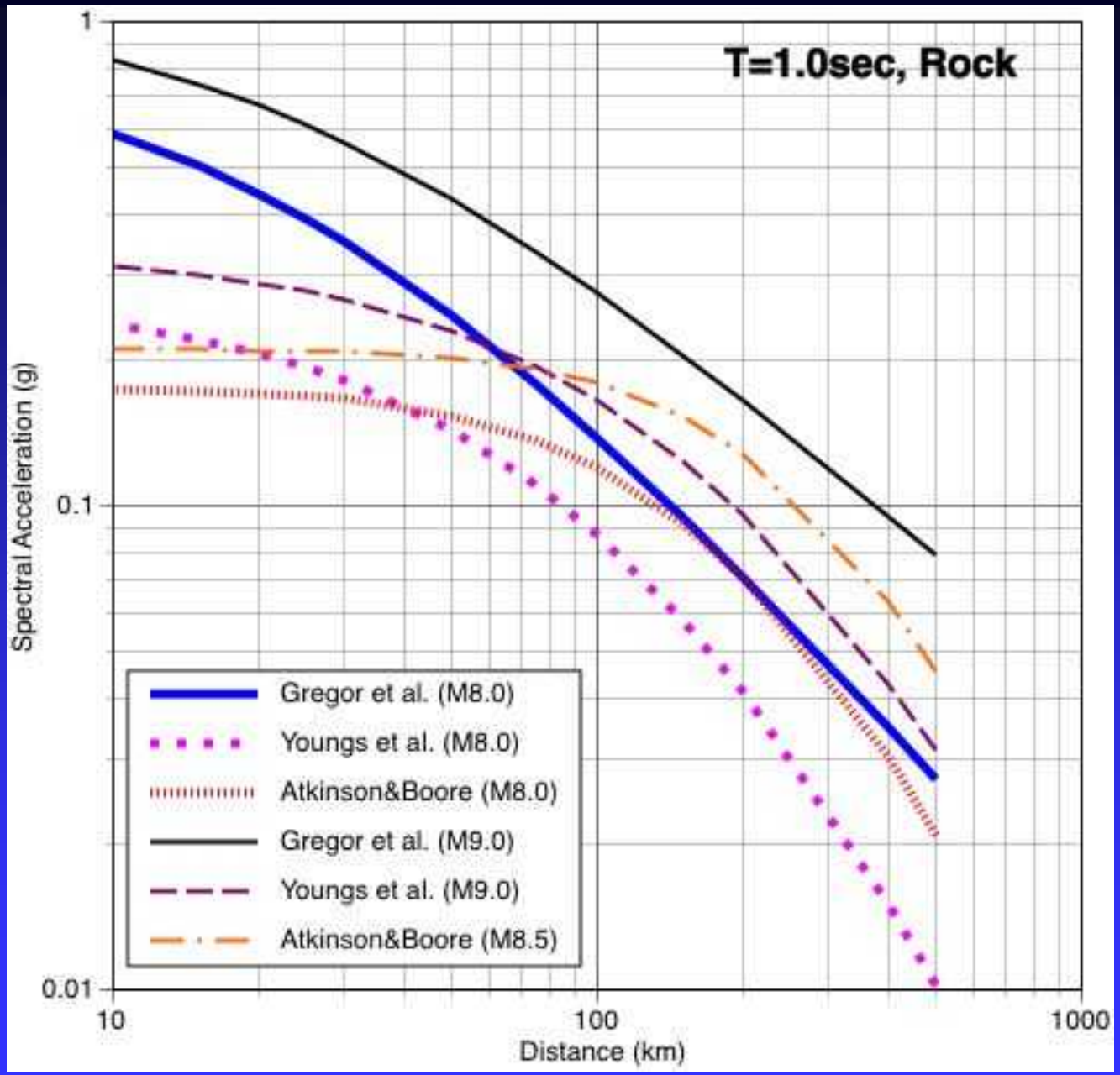

Site Amplification
10 1
10 0
10 -1
10 -1
10 0
10 1
10 2
Frequency (hz)
NEHRP D, 190 M/SEC, IMPERIAL
INPUT MOTION 0.001 G
LEGEND
50 FT, 50TH PERCENTILE
120 FT, 50TH PERCENTILE
250 FT, 50TH PERCENTILE
500 FT, 50TH PERCENTILE
1000 FT, 50TH PERCENTILE
2000 FT, 50TH PERCENTILE
3000 FT, 50TH PERCENTILE

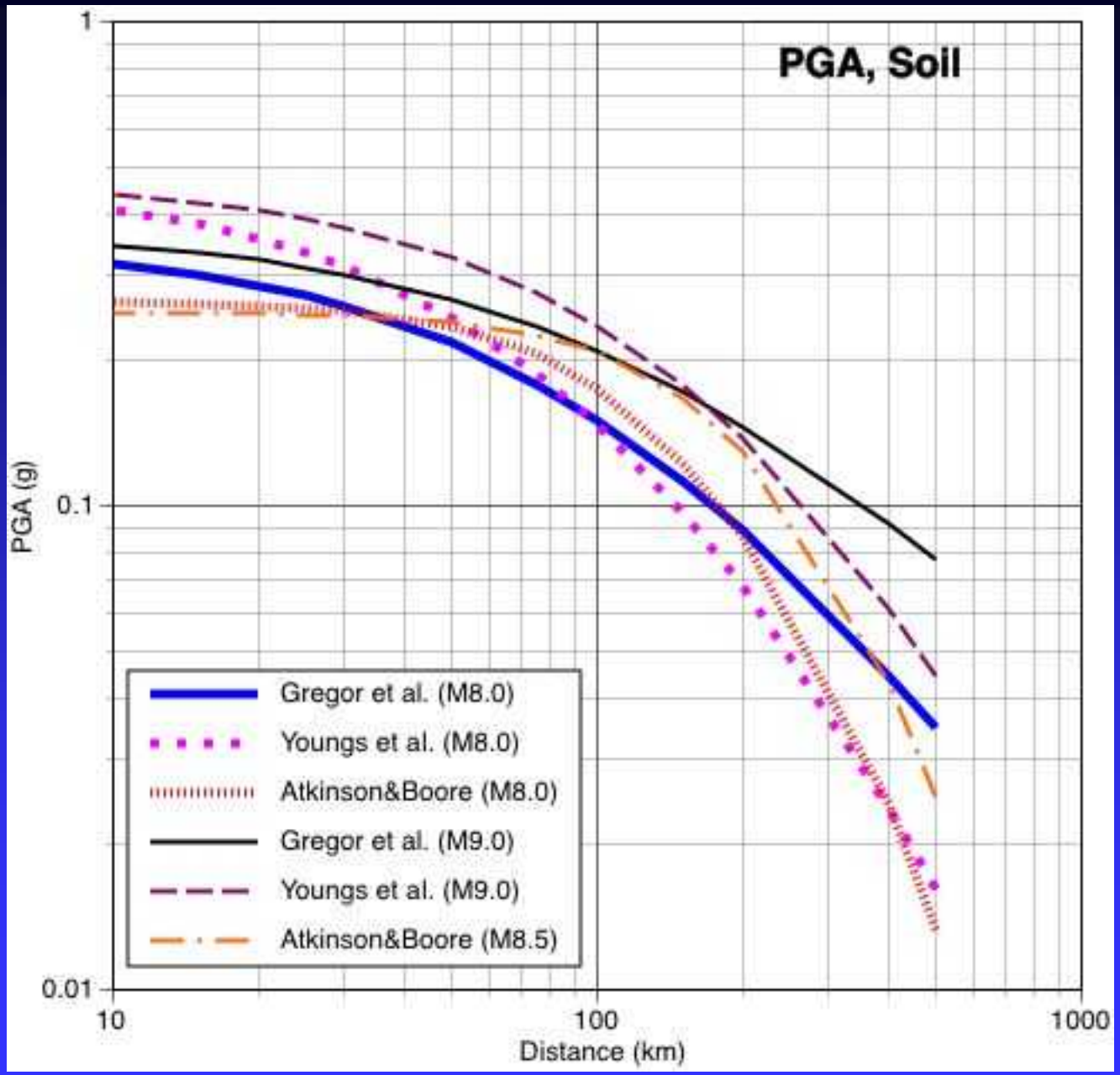

Peak Ground Acceleration (g)
10
1
0.1
0.01
0.001
1
10
100
1000
Rupture Distance (km)
Mw=8.0 Data: East Branch
Mw=8.0 Data: SE Branch
Mw=8.0 Rock Regression Model

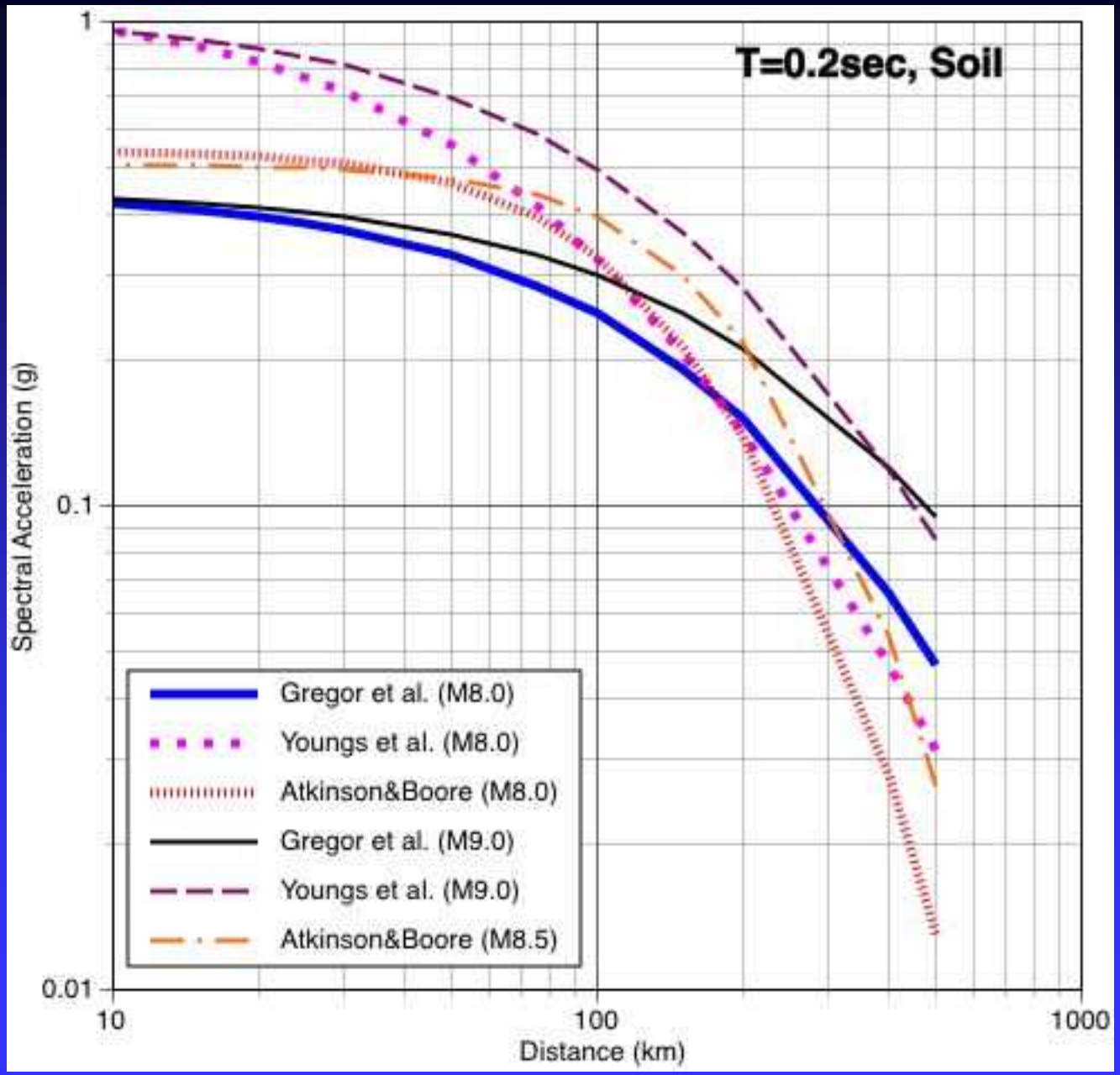

Peak Ground Acceleration (g)
10
1
0.1
0.01
0.001
1
10
100
1000
Rupture Distance (km)
Mw=9.0 Data: East Branch
Mw=9.0 Data: SE Branch
Mw=9.0 Rock Regression Model

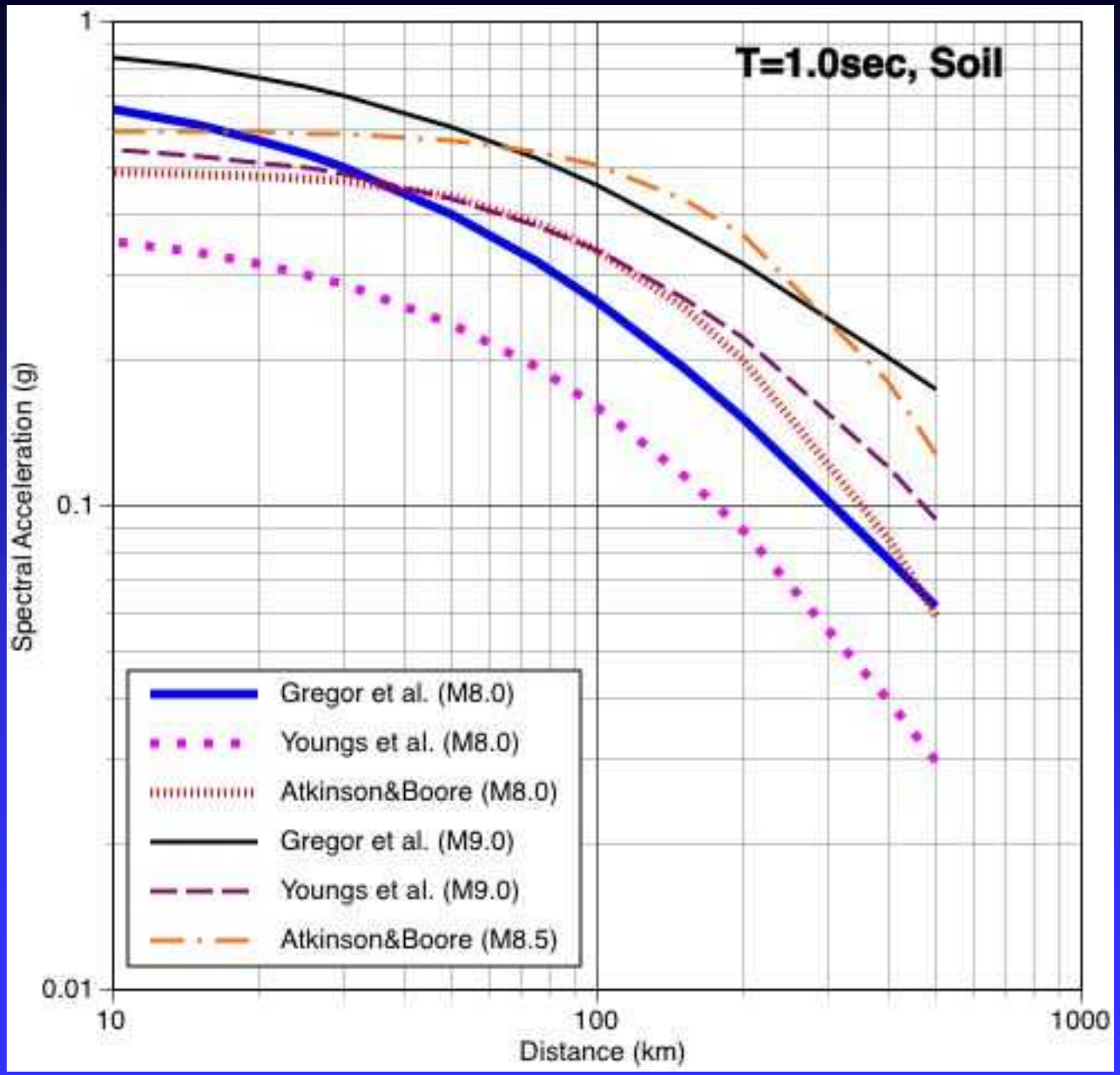

PGA, Rock
1
0.1
0.01
0.001
PGA (g)
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

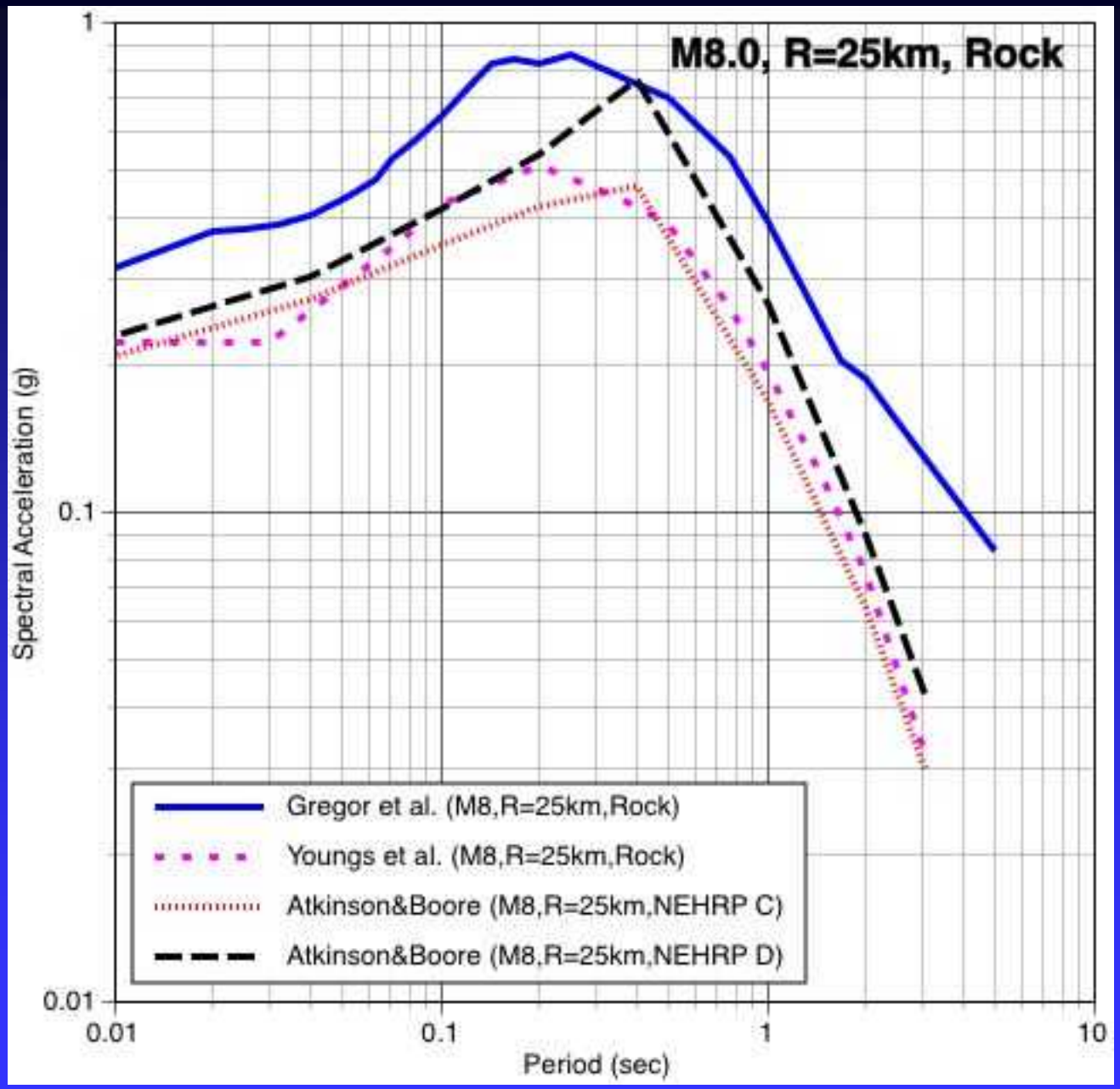

T=0.2sec, Rock
Spectral Acceleration (g)
10
1
0.1
0.01
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

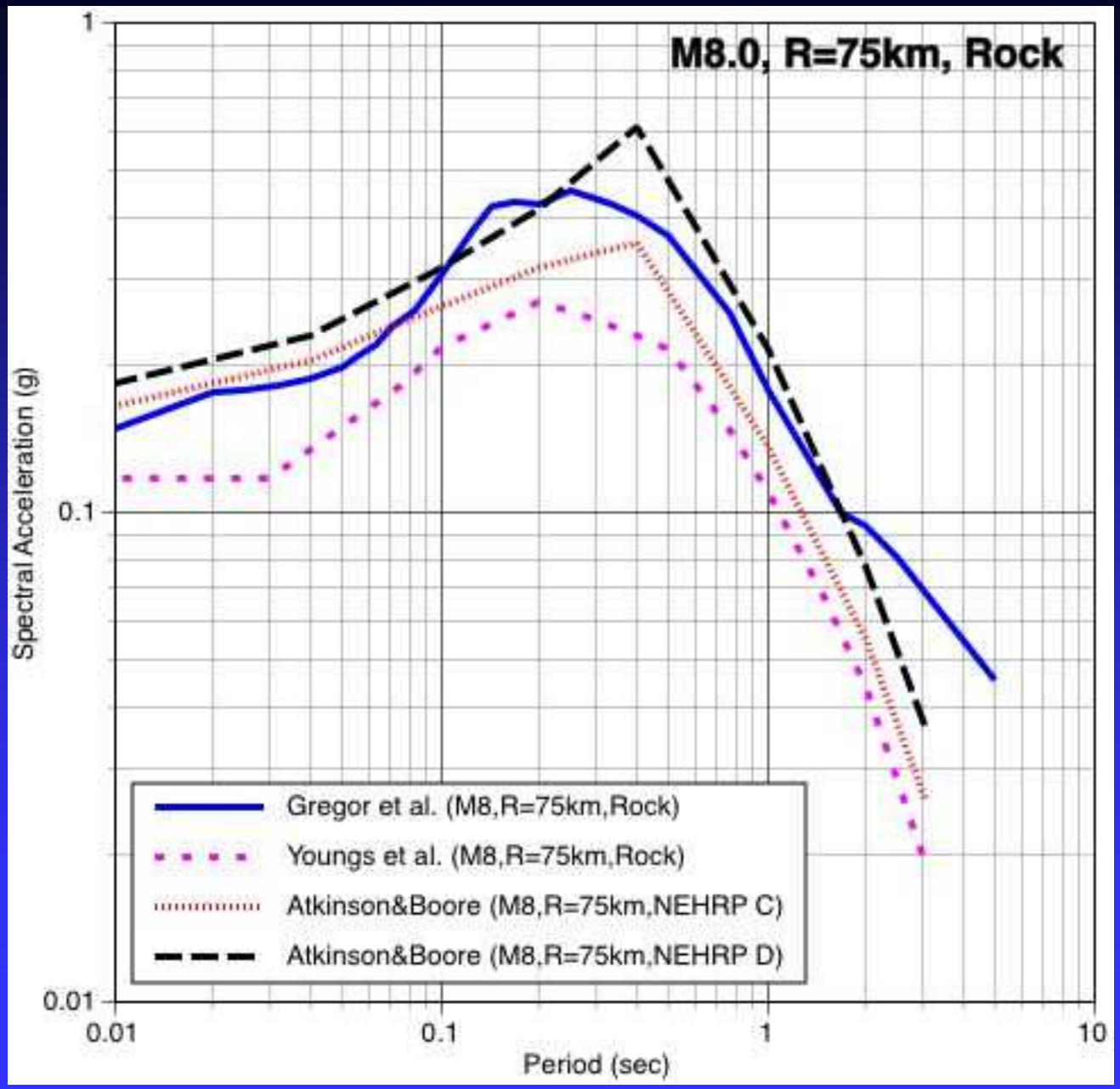

T=1.0sec, Rock
Spectral Acceleration (g)
1
0.1
0.01
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

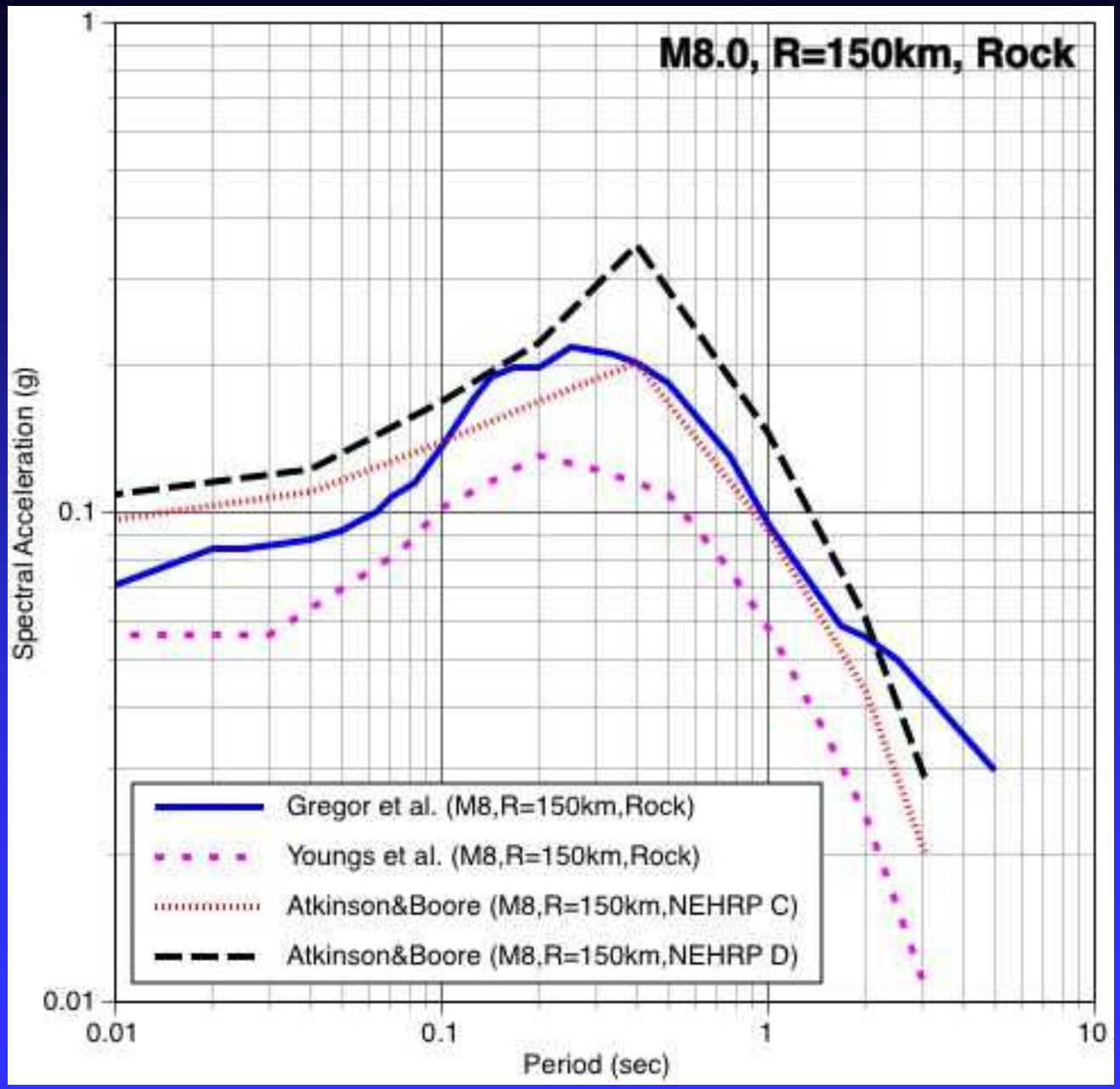

PGA, Soil
PGA (g)
1
0.1
0.01
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

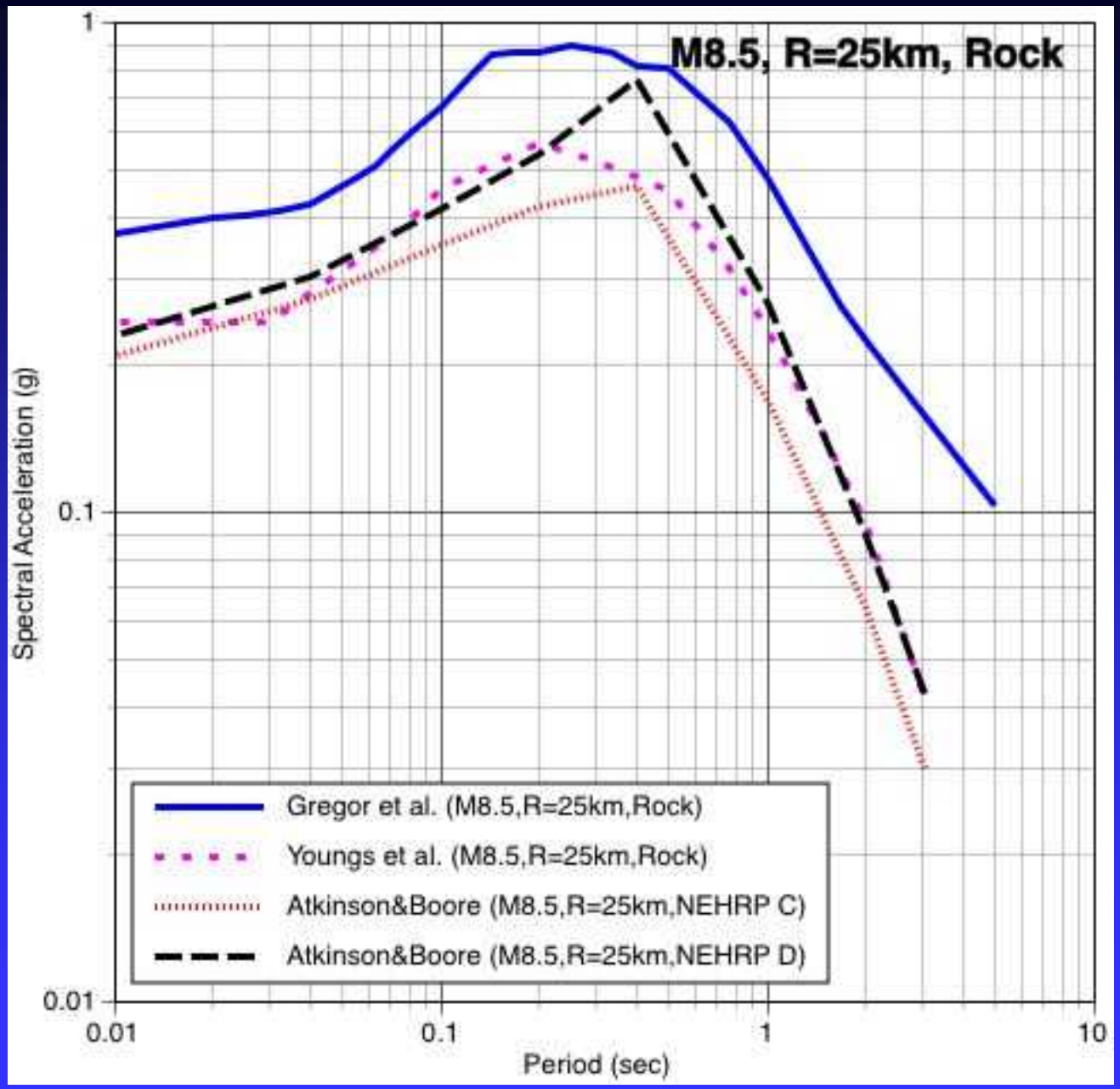

T=0.2sec, Soil
Spectral Acceleration (g)
1
0.1
0.01
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

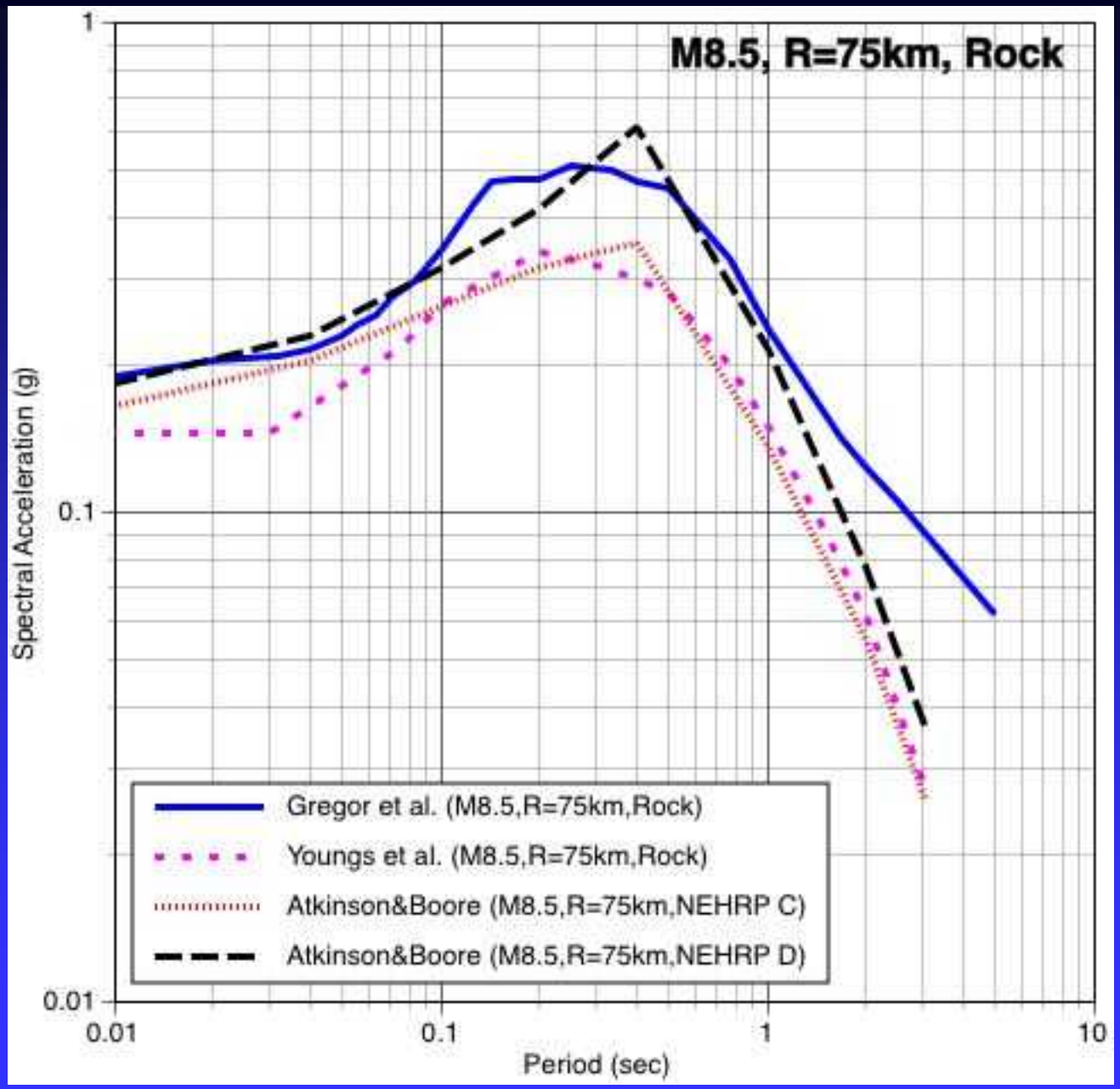

T=1.0sec, Soil
Spectral Acceleration (g)
1
0.1
0.01
10
100
1000
Distance (km)
Gregor et al. (M8.0)
Youngs et al. (M8.0)
Atkinson&Boore (M8.0)
Gregor et al. (M9.0)
Youngs et al. (M9.0)
Atkinson&Boore (M8.5)

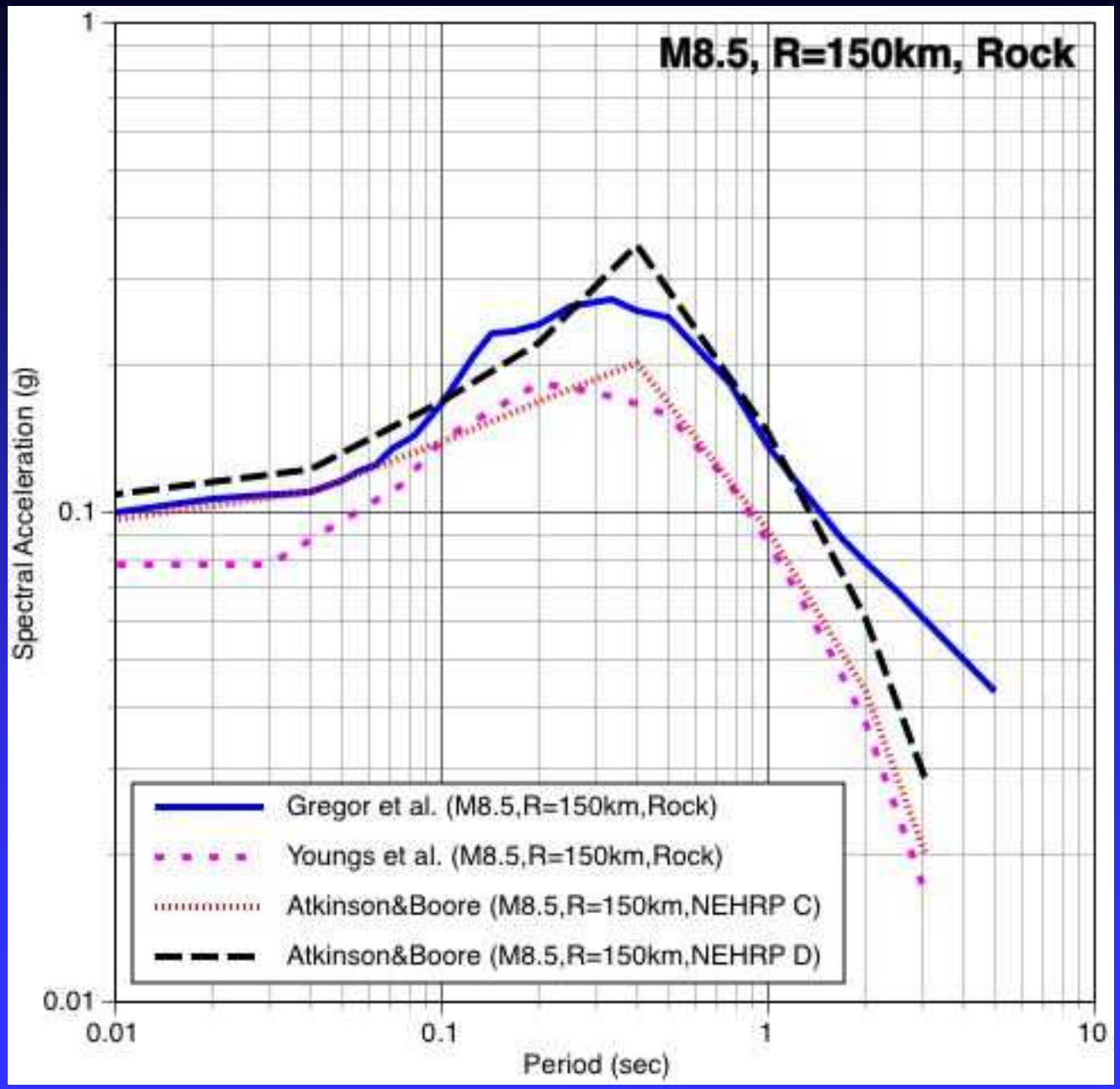

M8.0, R=25km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=25km,Rock)
Youngs et al. (M8,R=25km,Rock)
Atkinson&Boore (M8,R=25km,NEHRP C)
Atkinson&Boore (M8,R=25km,NEHRP D)

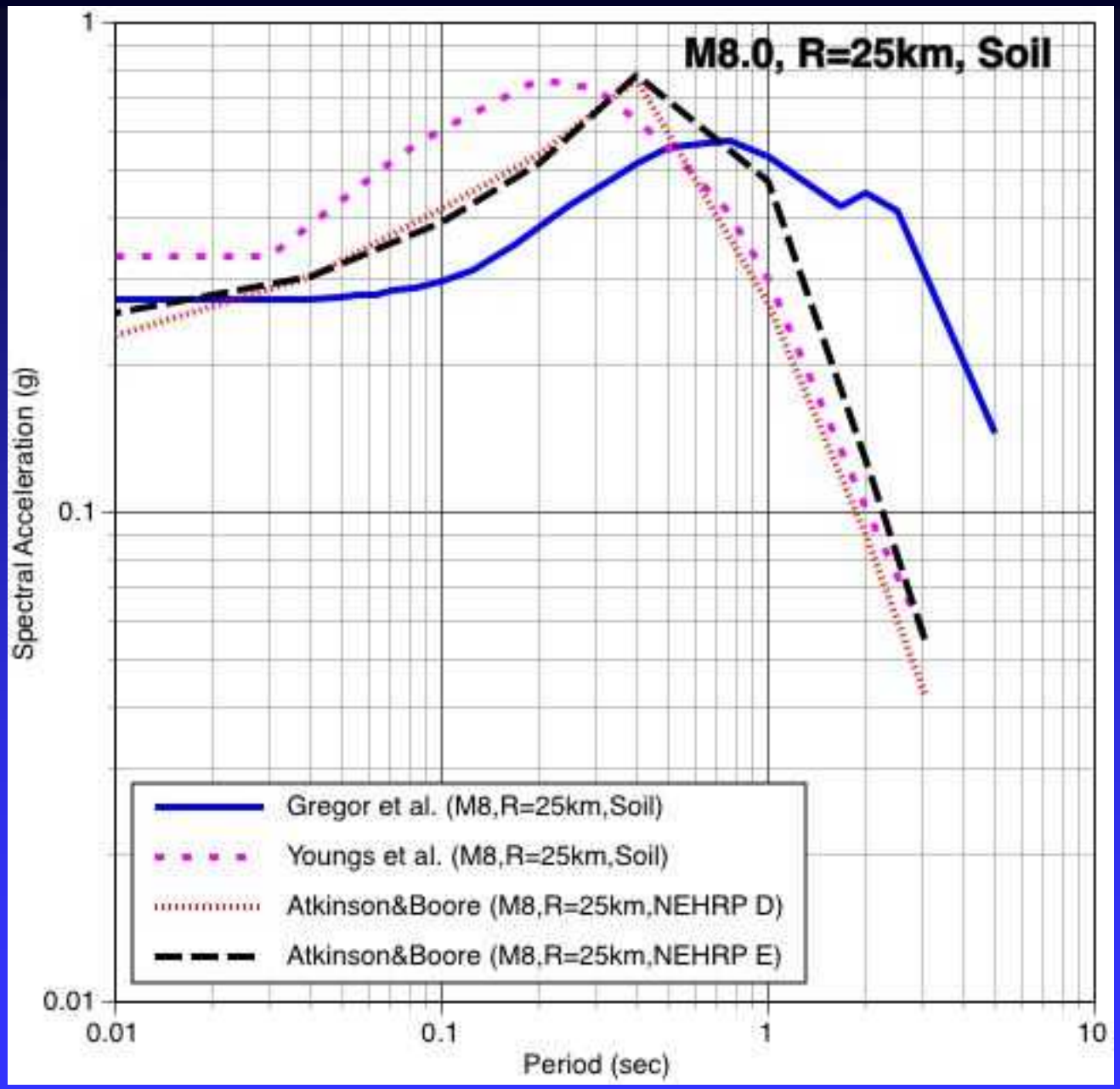

M8.0, R=75km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=75km,Rock)
Youngs et al. (M8,R=75km,Rock)
Atkinson&Boore (M8,R=75km,NEHRP C)
Atkinson&Boore (M8,R=75km,NEHRP D)

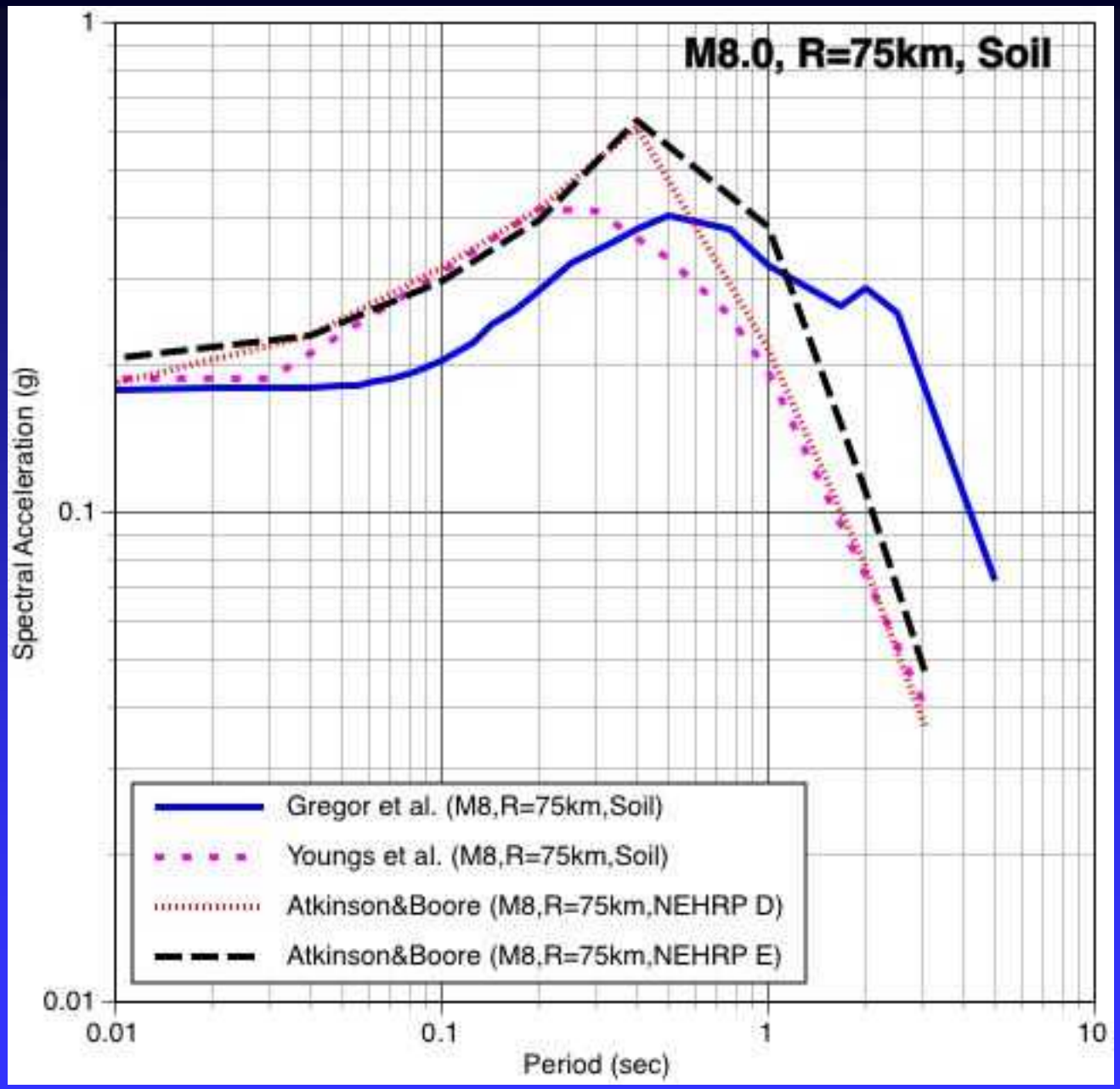

M8.0, R=150km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=150km,Rock)
Youngs et al. (M8,R=150km,Rock)
Atkinson&Boore (M8,R=150km,NEHRP C)
Atkinson&Boore (M8,R=150km,NEHRP D)

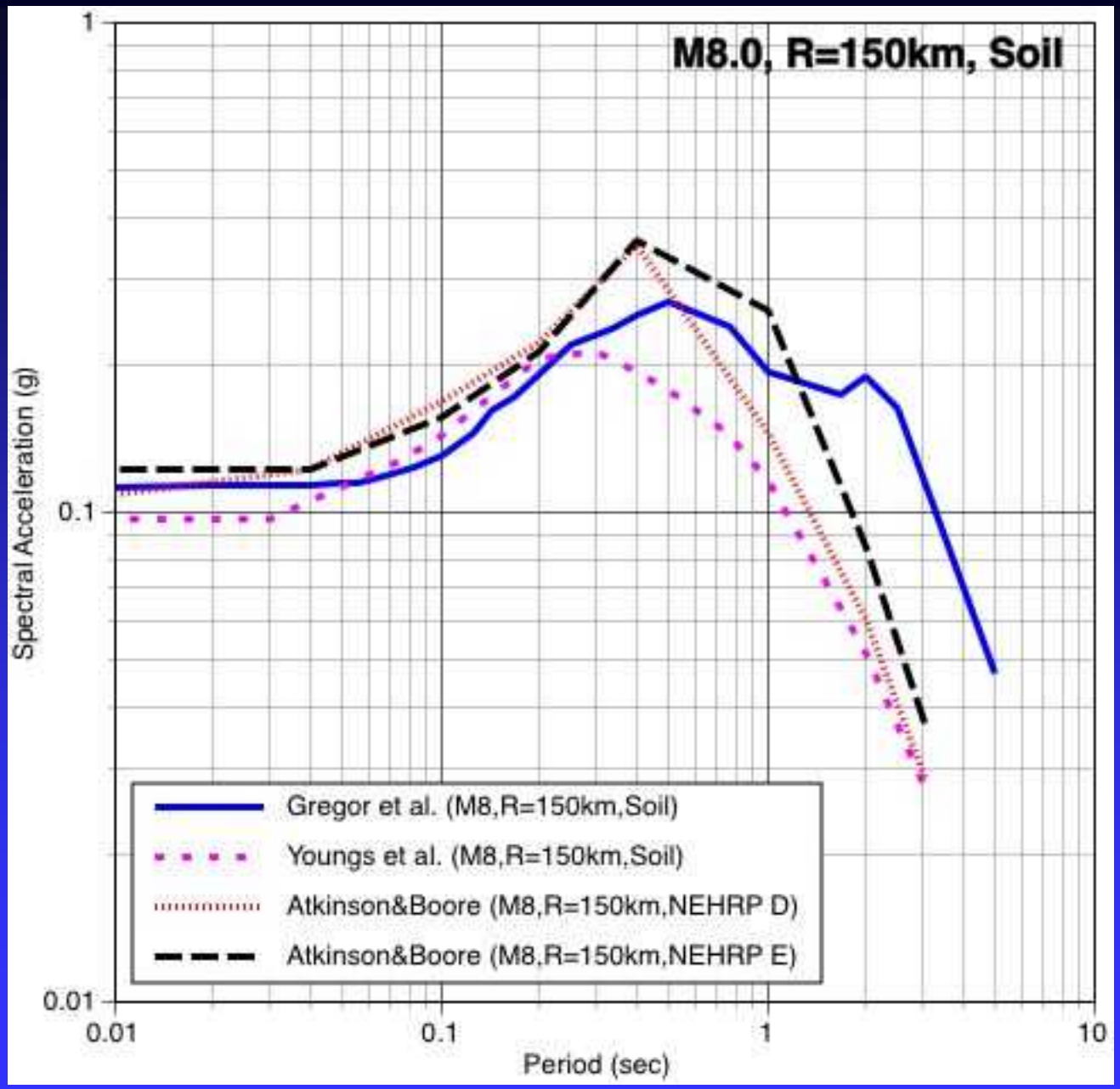

M8.5, R=25km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=25km,Rock)
Youngs et al. (M8.5,R=25km,Rock)
Atkinson&Boore (M8.5,R=25km,NEHRP C)
Atkinson&Boore (M8.5,R=25km,NEHRP D)

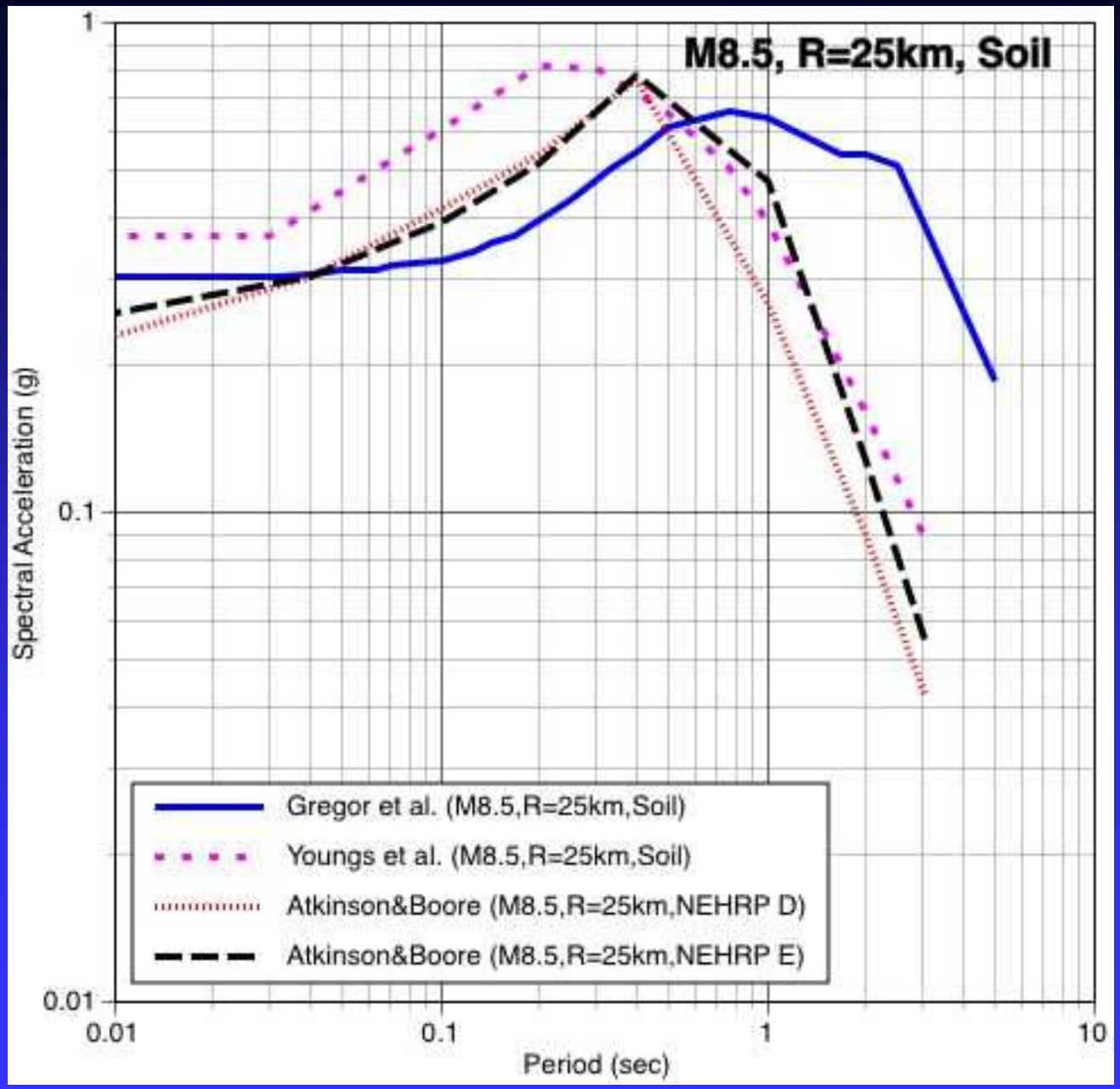

M8.5, R=75km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=75km,Rock)
Youngs et al. (M8.5,R=75km,Rock)
Atkinson&Boore (M8.5,R=75km,NEHRP C)
Atkinson&Boore (M8.5,R=75km,NEHRP D)

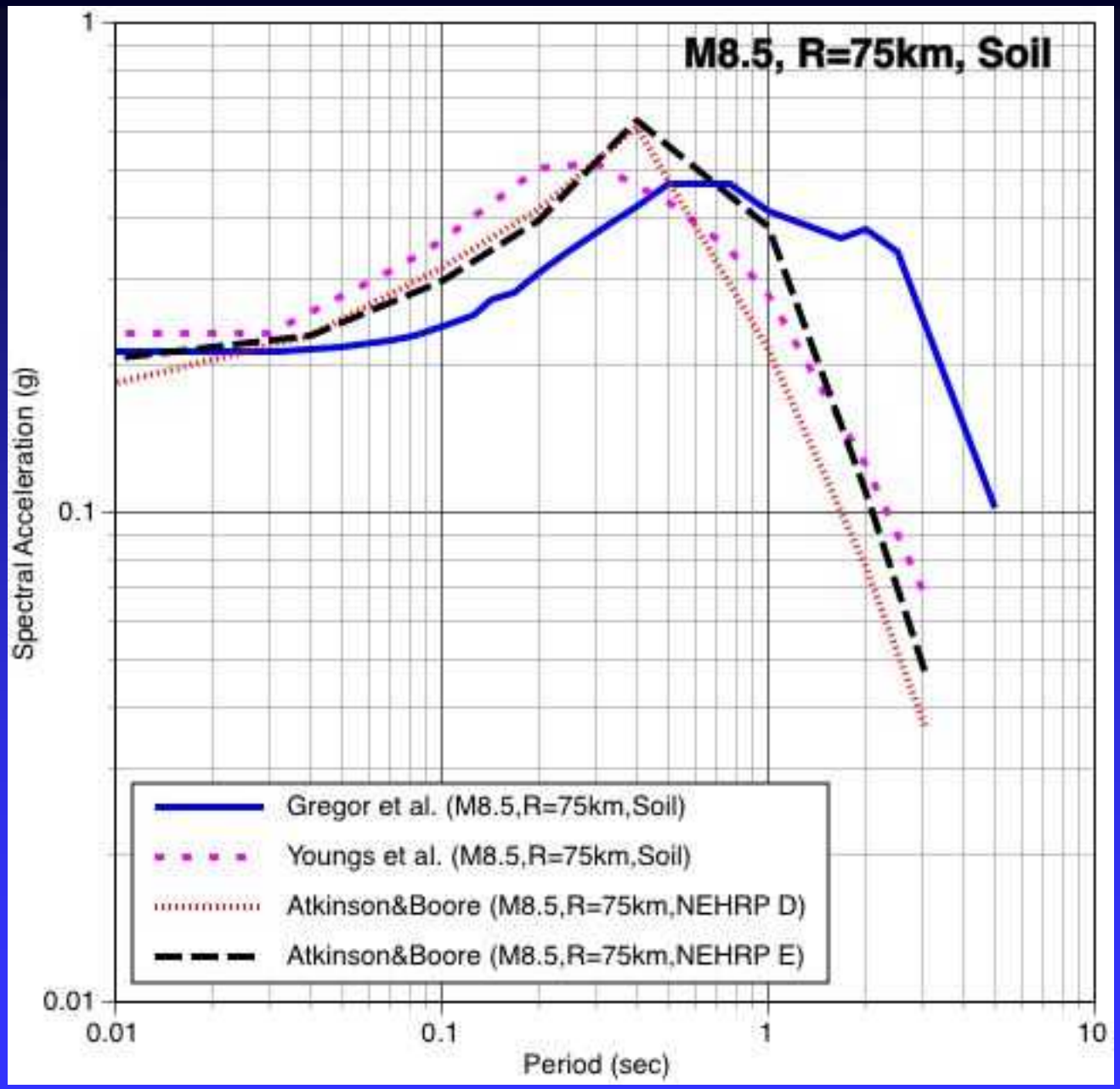

M8.5, R=150km, Rock
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=150km,Rock)
Youngs et al. (M8.5,R=150km,Rock)
Atkinson&Boore (M8.5,R=150km,NEHRP C)
Atkinson&Boore (M8.5,R=150km,NEHRP D)

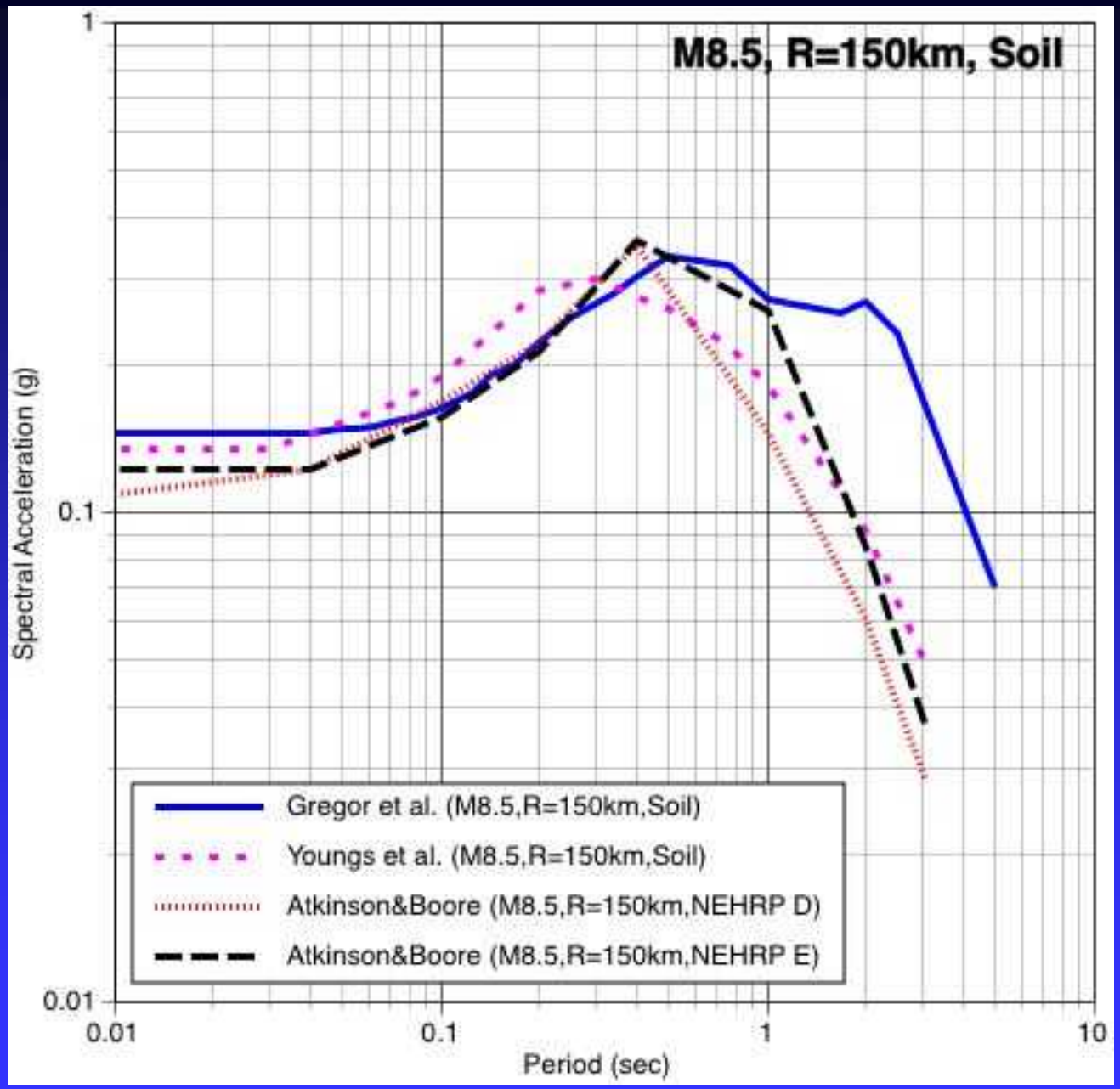

M8.0, R=25km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=25km,Soil)
Youngs et al. (M8,R=25km,Soil)
Atkinson&Boore (M8,R=25km,NEHRP D)
Atkinson&Boore (M8,R=25km,NEHRP E)

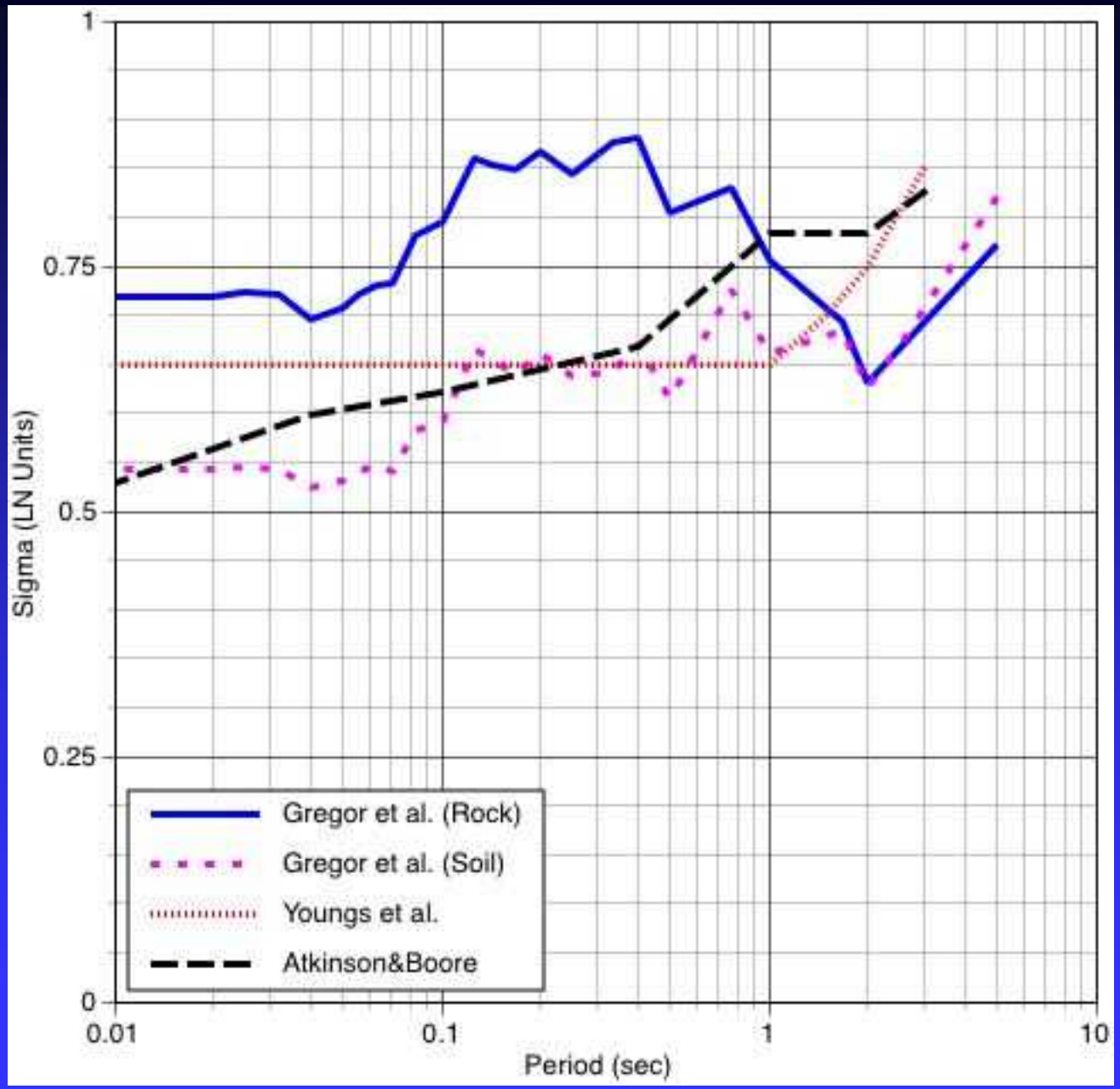

M8.0, R=75km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=75km,Soil)
Youngs et al. (M8,R=75km,Soil)
Atkinson&Boore (M8,R=75km,NEHRP D)
Atkinson&Boore (M8,R=75km,NEHRP E)


M8.0, R=150km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8,R=150km,Soil)
Youngs et al. (M8,R=150km,Soil)
Atkinson&Boore (M8,R=150km,NEHRP D)
Atkinson&Boore (M8,R=150km,NEHRP E)


M8.5, R=25km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=25km,Soil)
Youngs et al. (M8.5,R=25km,Soil)
Atkinson&Boore (M8.5,R=25km,NEHRP D)
Atkinson&Boore (M8.5,R=25km,NEHRP E)


M8.5, R=75km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=75km,Soil)
Youngs et al. (M8.5,R=75km,Soil)
Atkinson&Boore (M8.5,R=75km,NEHRP D)
Atkinson&Boore (M8.5,R=75km,NEHRP E)

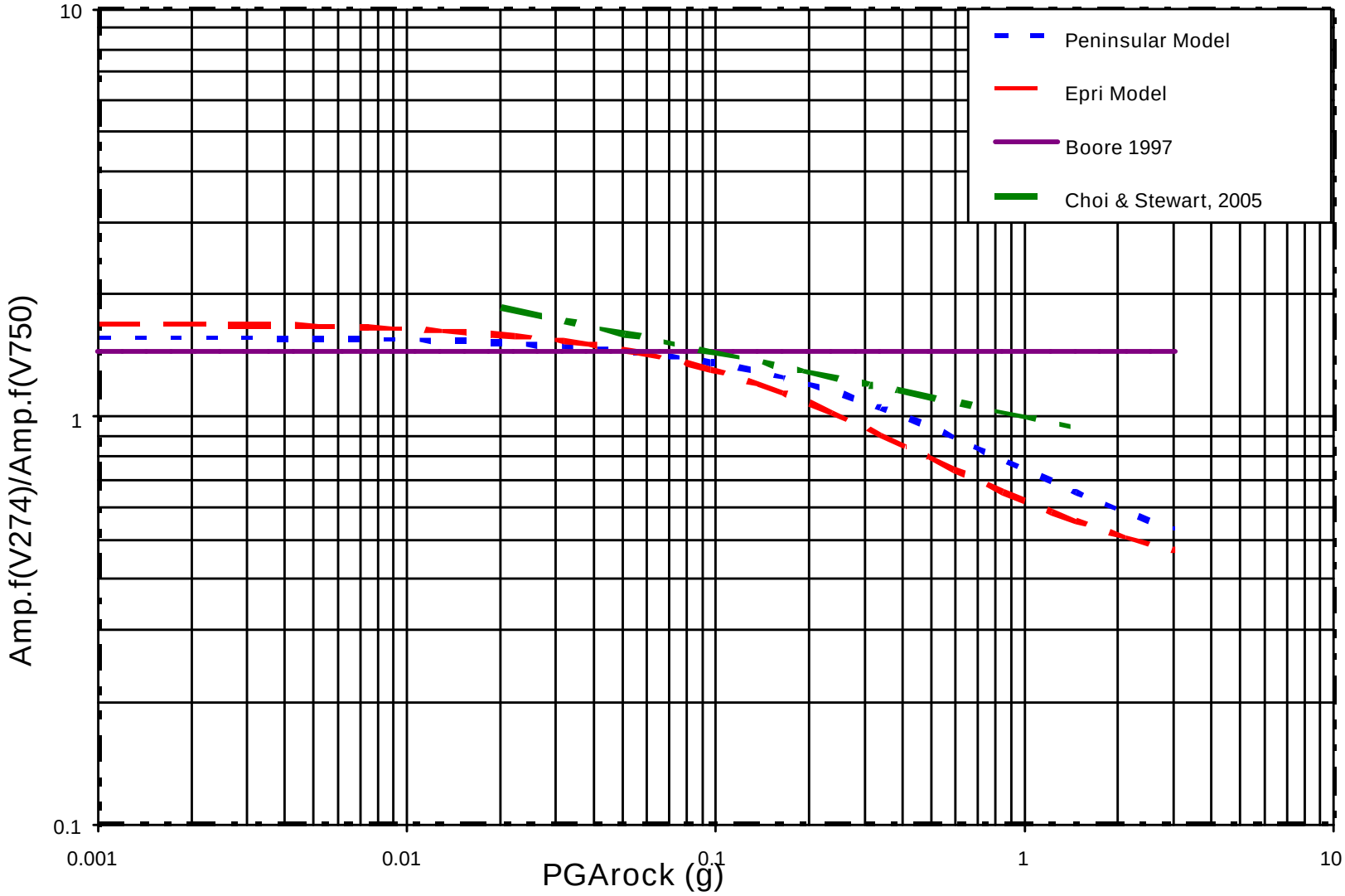

M8.5, R=150km, Soil
Spectral Acceleration (g)
1
0.1
0.01
0.01
0.1
1
10
Period (sec)
Gregor et al. (M8.5,R=150km,Soil)
Youngs et al. (M8.5,R=150km,Soil)
Atkinson&Boore (M8.5,R=150km,NEHRP D)
Atkinson&Boore (M8.5,R=150km,NEHRP E)


1
0.75
0.5
0.25
0
Sigma (LN Units)
0.01
0.1
1
10
Period (sec)
Gregor et al. (Rock)
Gregor et al. (Soil)
Youngs et al.
Atkinson&Boore

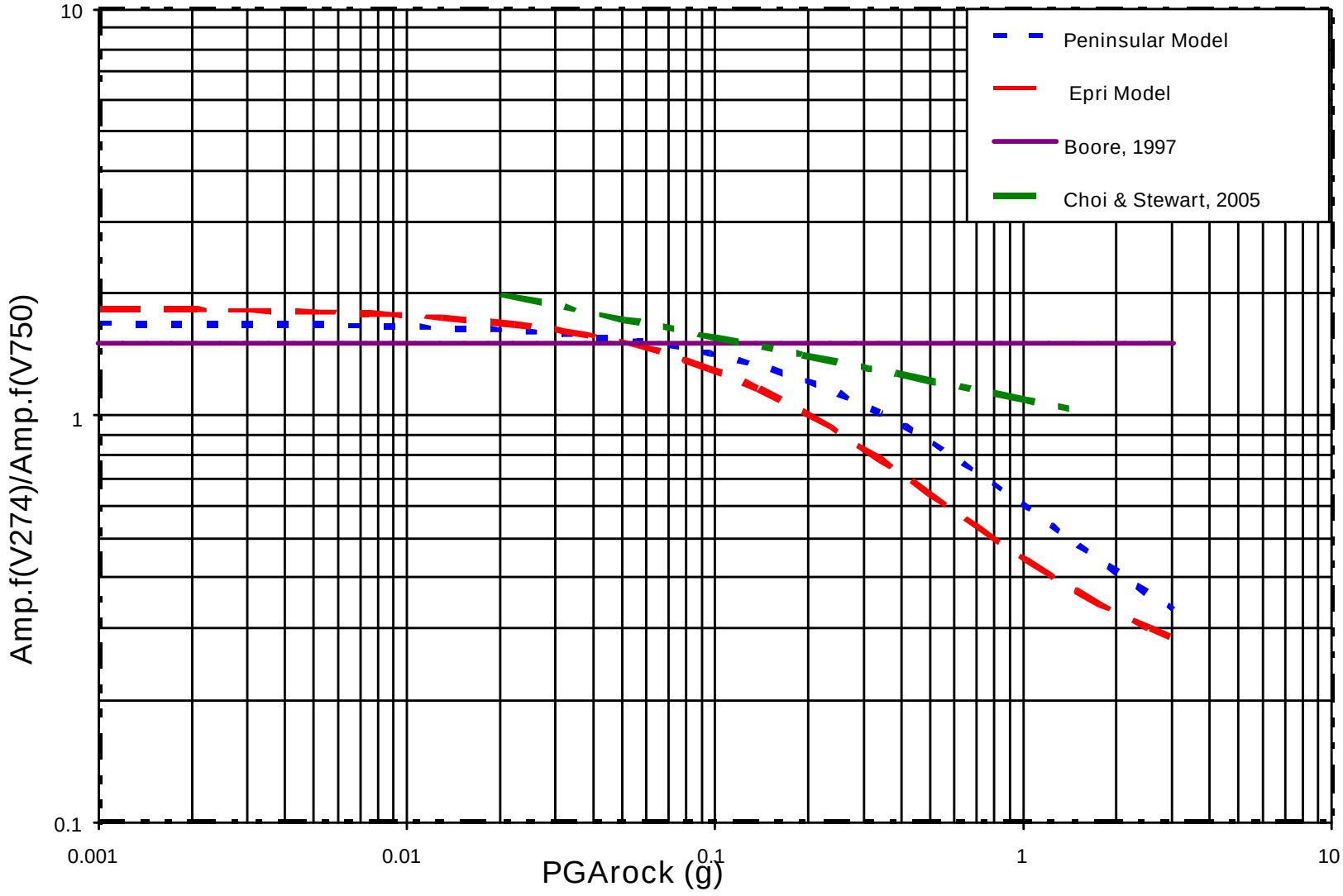
Attenuation Model Update

- Non-linear Site Response Model from PEER NGA (Walling and Abrahamson, 2006)
- Reference "Rock" Vs_{30m}=1,100 m/sec
- Vs_{30m} range: 270 - 2,830 m/sec
- Depth range: 30 - 1,000 feet
- EPRI and Penisular Soil Curves
- Input Rock PGA range: 0.01 - 1.5 g

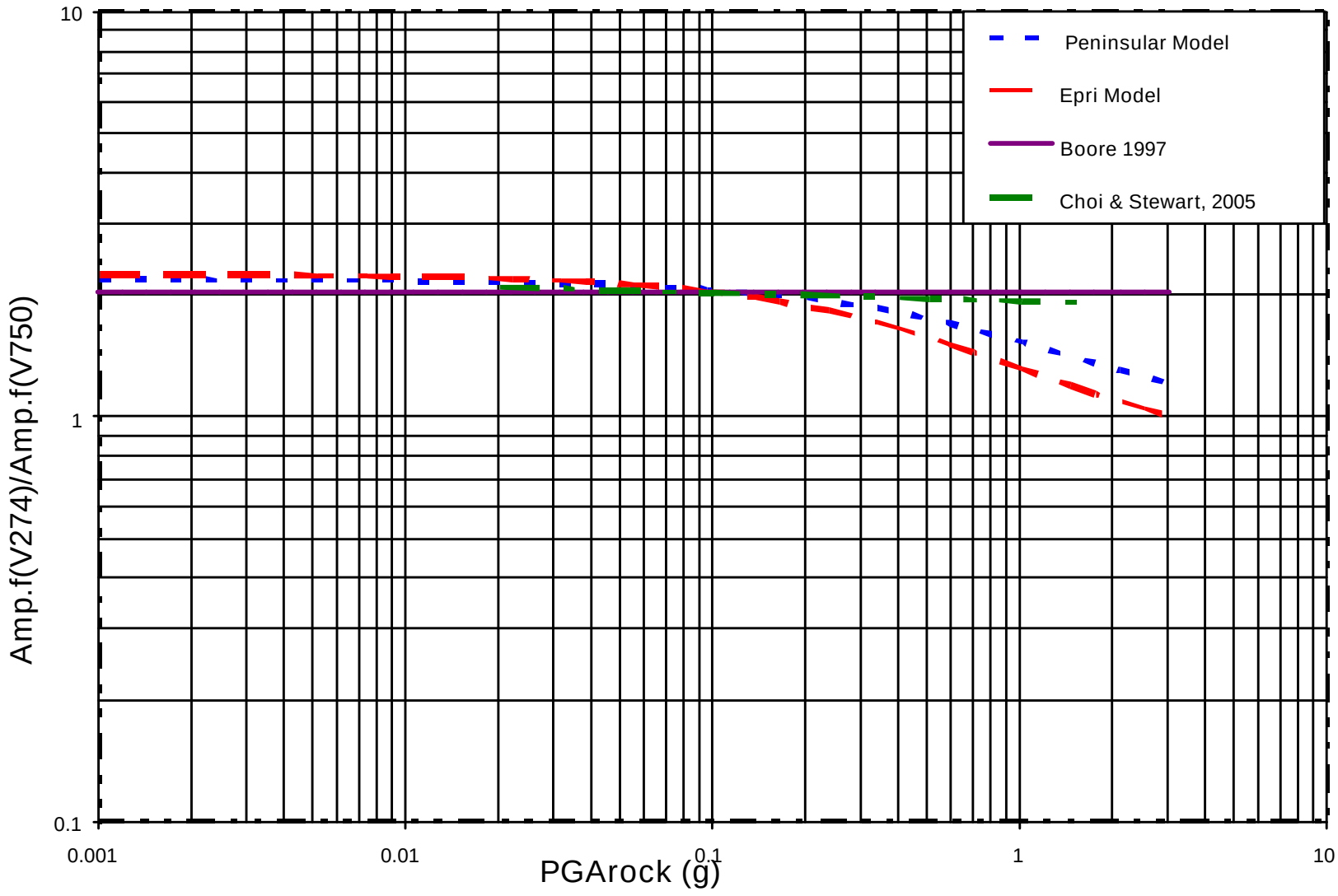
PGA


Peninsular Model
Epri Model
Boore 1997
Choi & Stewart, 2005
Amp.f(V274)/Amp.f(V750)
PGArock (g)
10
1
0.1
0.001
0.01
0.1
1
10

T=0.3 sec


Peninsular Model
Epri Model
Boore, 1997
Choi & Stewart, 2005
Amp.f(V274)/Amp.f(V750)
PGArock (g)
10
1
0.1
0.001
0.01
0.1
1
10

T=1.0 sec


Peninsular Model
Epri Model
Boore 1997
Choi & Stewart, 2005
Amp.f(V274)/Amp.f(V750)
10
1
0.1
0.001
0.01
0.1
1
10
PGArock (g)