The Institution of Structural Engineers Caribbean Division

Caribbean Conference on Earthquake Engineering

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Geotechnical And Foundation Engineering Sieismology Considerations

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1615.1 General procedure for determining Maximum Considered Earthquake and design spectral response

1615.1.1 Site Class Definitions; F_a, F_v

1615.1.2 Site Coefficients and adjusted MCE spectral response acceleration parameters. S_s and S_1 from maps and $S_{MS} = F_a * S_s$ and $S_{M1} = F_v * S_1$

1615.1.3 Design spectral acceleration parameters; $S_{DS} = 2/3 * S_{MS}$, $S_{D1} = 2/3 * S_{M1}$

1615.1.4 General procedure response spectrum.

1615.1.5 Site Classification for seismic design.

1615.2 Site-specific procedure for determining ground motion accelerations

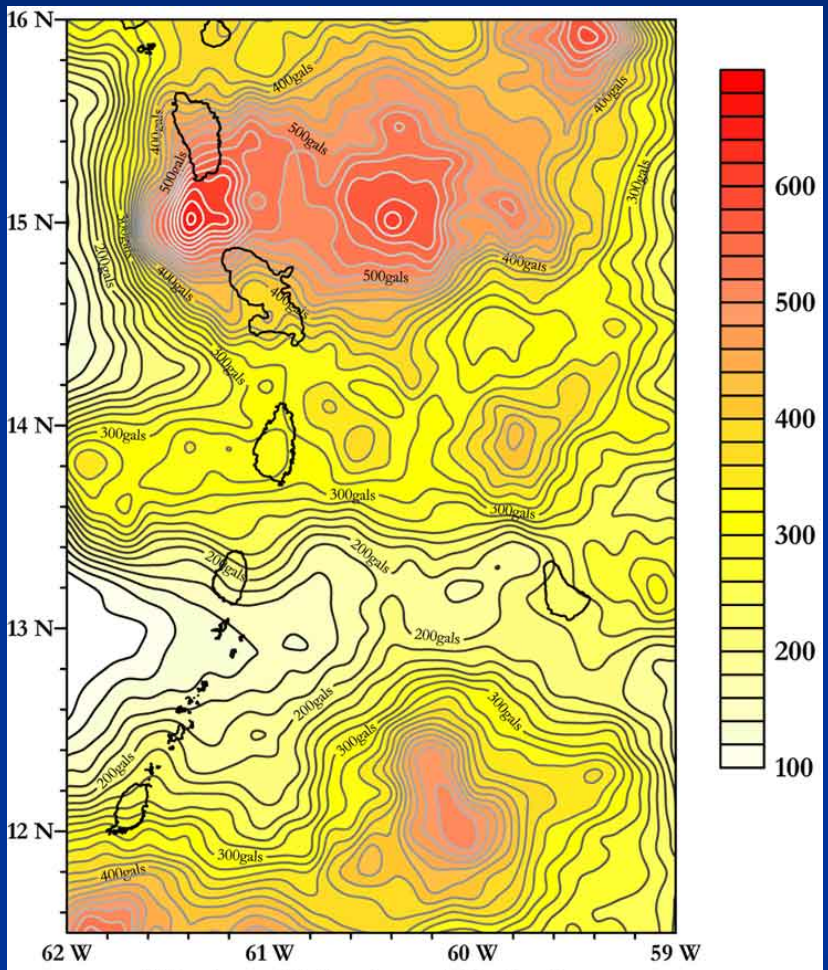
1615.1.1 Site Class Definitions.

TABLE 1615.1.1
SITE CLASS DEFINITIONS

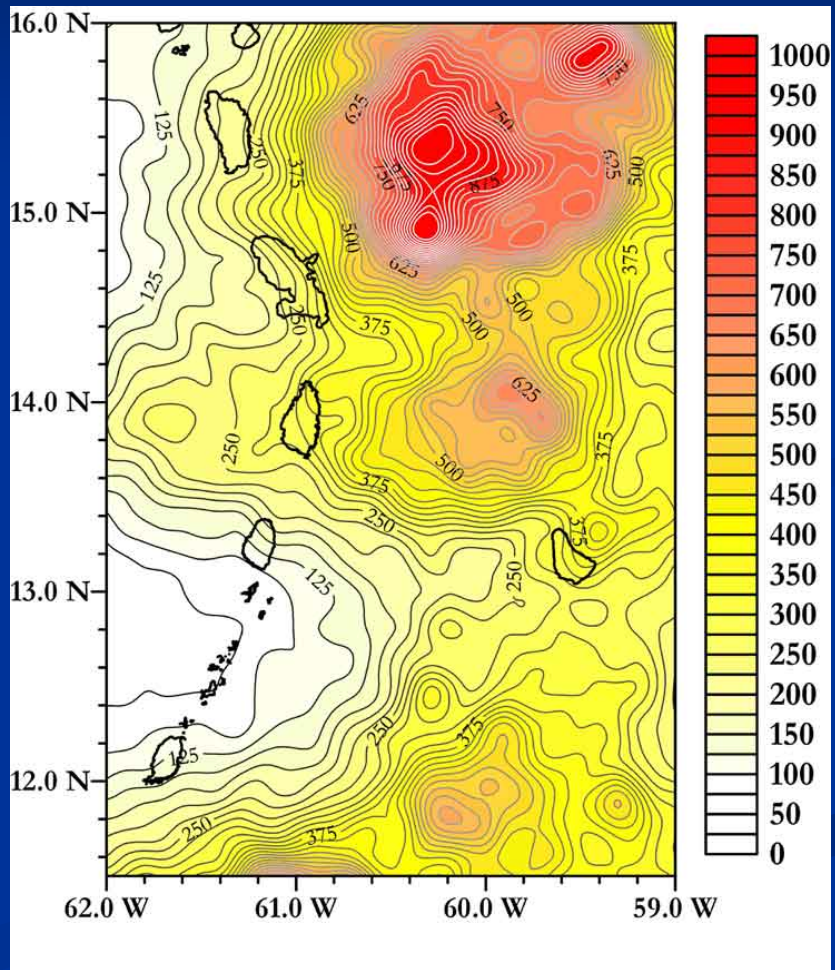
SITE CLASS	SOIL PROFILE NAME	AVERAGE PROPERTIES IN TOP 100 feet, AS PER SECTION 1615.1.5		
		Soil shear wave velocity, $\bar{v}_s$, (ft/s)	Standard penetration resistance, $\bar{N}$	Soil undrained shear strength, $\bar{s}_u$, (psf)
A	Hard rock	$\bar{v}_s > 5{,}000$	N/A	N/A
B	Rock	$2{,}500 < \bar{v}_s \leq 5{,}000$	N/A	N/A
C	Very dense soil and soft rock	$1{,}200 < \bar{v}_s \leq 2{,}500$	$\bar{N} > 50$	$\bar{s}_u \geq 2{,}000$
D	Stiff soil profile	$600 \leq \bar{v}_s \leq 1{,}200$	$15 \leq \bar{N} \leq 50$	$1{,}000 \leq \bar{s}_u \leq 2{,}000$
E	Soft soil profile	$\bar{v}_s < 600$	$\bar{N} < 15$	$\bar{s}_u < 1{,}000$
E	—	Any profile with more than 10 feet of soil having the following characteristics: 1. Plasticity index $PI > 20$, 2. Moisture content $w \geq 40\%$, and 3. Undrained shear strength $\bar{s}_u < 500$ psf		
F	—	Any profile containing soils having one or more of the following characteristics: 1. Soils vulnerable to potential failure or collapse under seismic loading such as liquefiable soils, quick and highly sensitive clays, collapsible weakly cemented soils. 2. Peats and/or highly organic clays ($H > 10$ feet of peat and/or highly organic clay where H = thickness of soil) 3. Very high plasticity clays ($H > 25$ feet with plasticity index $PI > 75$) 4. Very thick soft/medium stiff clays ($H > 120$ feet)		

For SI: 1 foot = 304.8 mm, 1 square foot = 0.0929 m^2, 1 pound per square foot = 0.0479 kPa. N/A = Not applicable

1615.1.2 Site Coefficients and adjusted MCE spectral response acceleration parameters. S_s and S_1 from maps



Windward Islands and Barbados
Spectral acceleration at 0.2 second period.
2% probability in any 50-year period

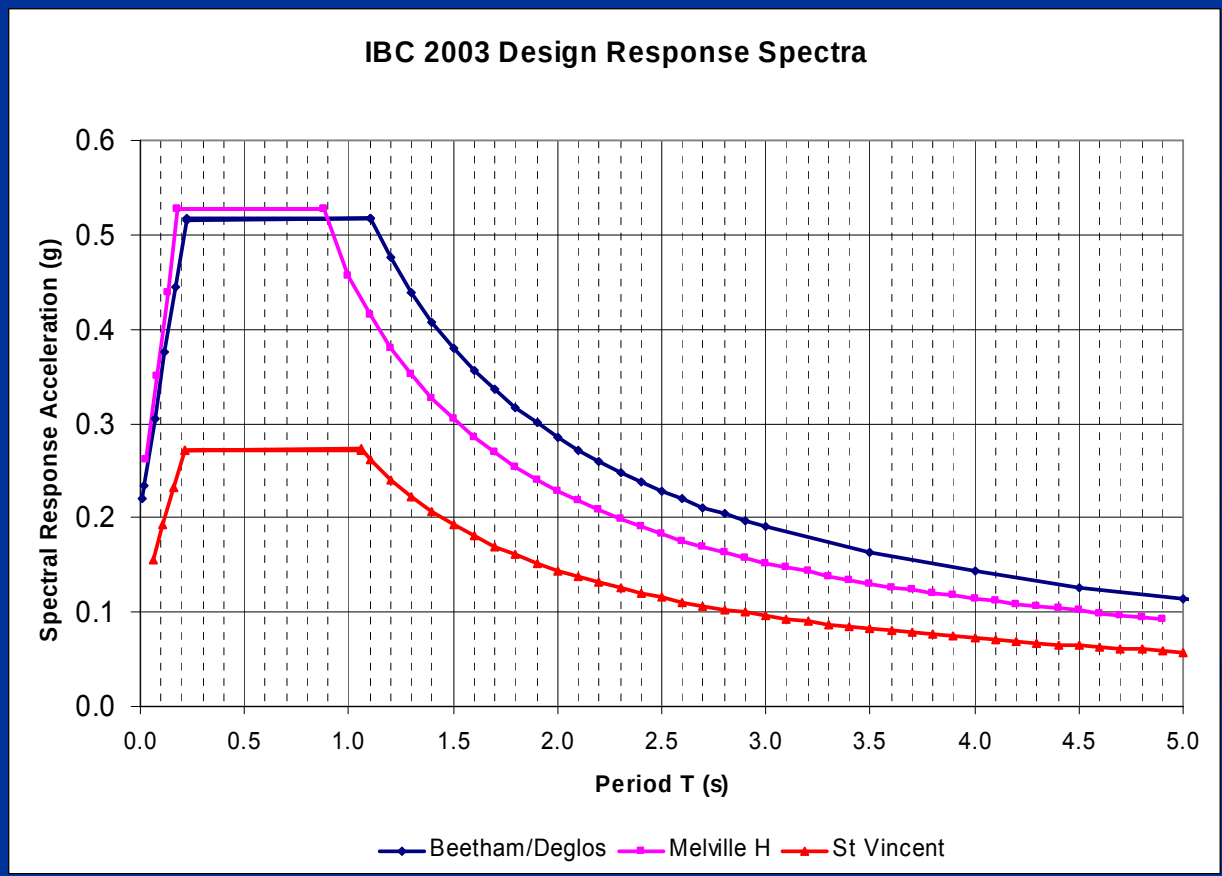


Wndward Islands and Barbados.
Spectral acceleration at 1.0 second period
2% probability in any 50-year period

1615.1.3 Design spectral acceleration parameters

$S_{DS} = 2/3 * S_{MS}$, $S_{D1} = 2/3 * S_{M1}$

1615.1.3 General Procedure Response Spectrum



1615.1.5 Site Classification for Seismic Design

- Site Classification for Site Class C, D and E shall be determined from Table 1615.1.5; a profile depth of 30.5 m (100 ft) is considered. [Weighted averages are used in layered profiles]

- The **shear wave velocity v_s** for Site Class B, shall be either measured on site or estimated by a geotechnical engineer or engineering geologist/seismologist for competent rock with moderate weathering and fracturing. Softer and more highly fractured and weathered rock shall either be measured on site or or classified as Site Class C.

1615.1.5 Site Classification for Seismic Design (cont'd)

The hard rock, Site Class A, shall be supported by shear wave velocity V_s measurements either on site or on profiles of the same rock type in the same formation with an equal or greater degree of weathering and fracturing.

Other Parameters Required: Site Classes E & F

N = SPT (blows/ft)

Su = Undrained Shear strength (kN/m^2)

PI = Plasticity Index (w%)

w% = Water Content (%)

Estimation of Shear Wave Velocity from standard rock/soil parameters

$$V_P = \sqrt{\left(\frac{K+4\mu/3}{\rho}\right)} = \sqrt{\frac{(1-\sigma)E}{(1+\sigma)(1-2\sigma)\rho}}$$

$$V_S = \sqrt{\frac{\mu}{\rho}} = \sqrt{\frac{E}{\rho}\frac{1}{2(1+\sigma)}}$$

Vp = P wave velocity (body waves)

Vs = S or Shear wave velocity (body waves)

E = Youngs Modulus

μ = Shear Modulus

K= Bulk Modulus

ρ = Material Density

σ = Poisson Ratio

Estimation of Shear Wave Velocity from standard rock/soil parameters (Sharma 1997)

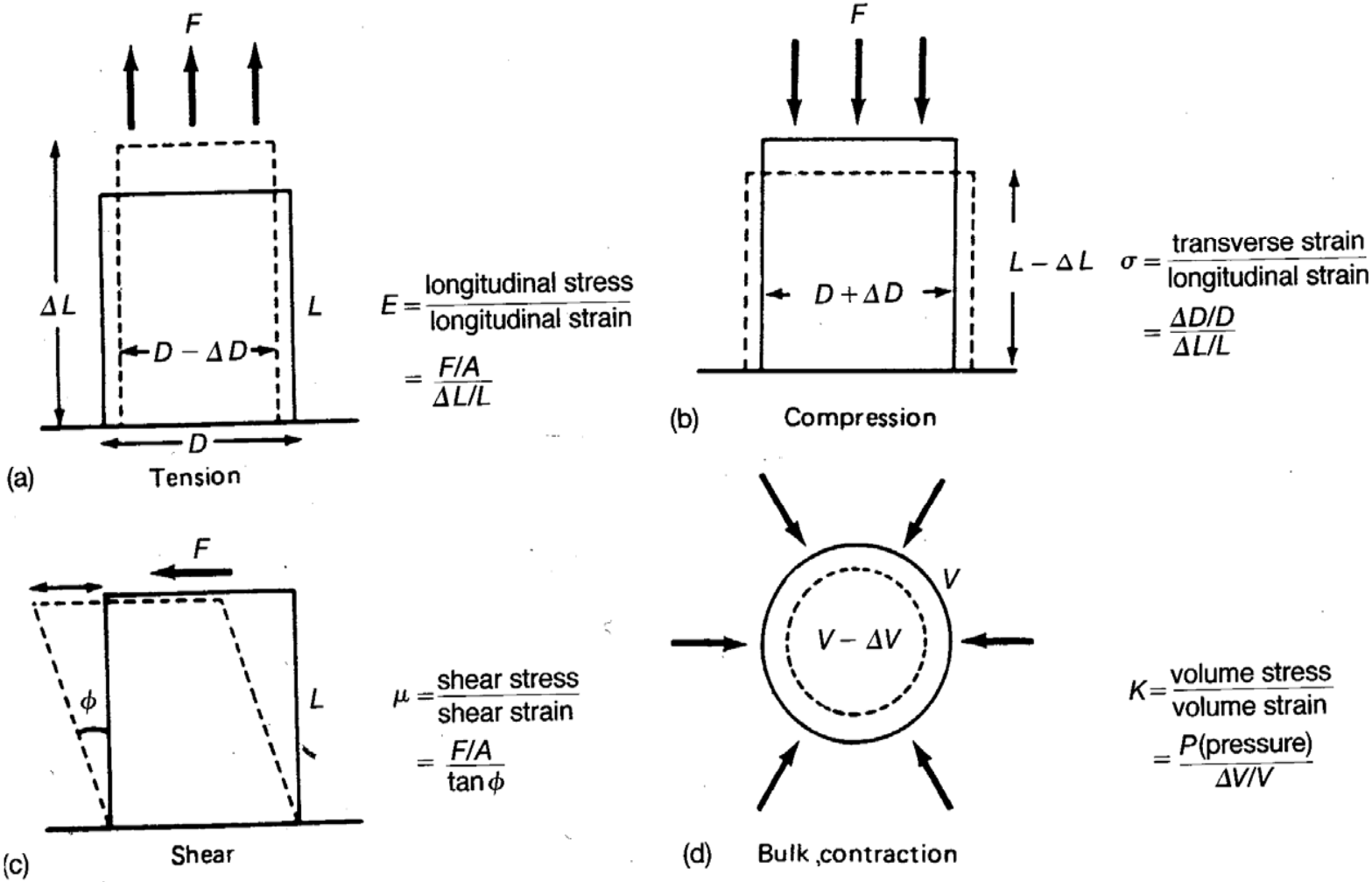
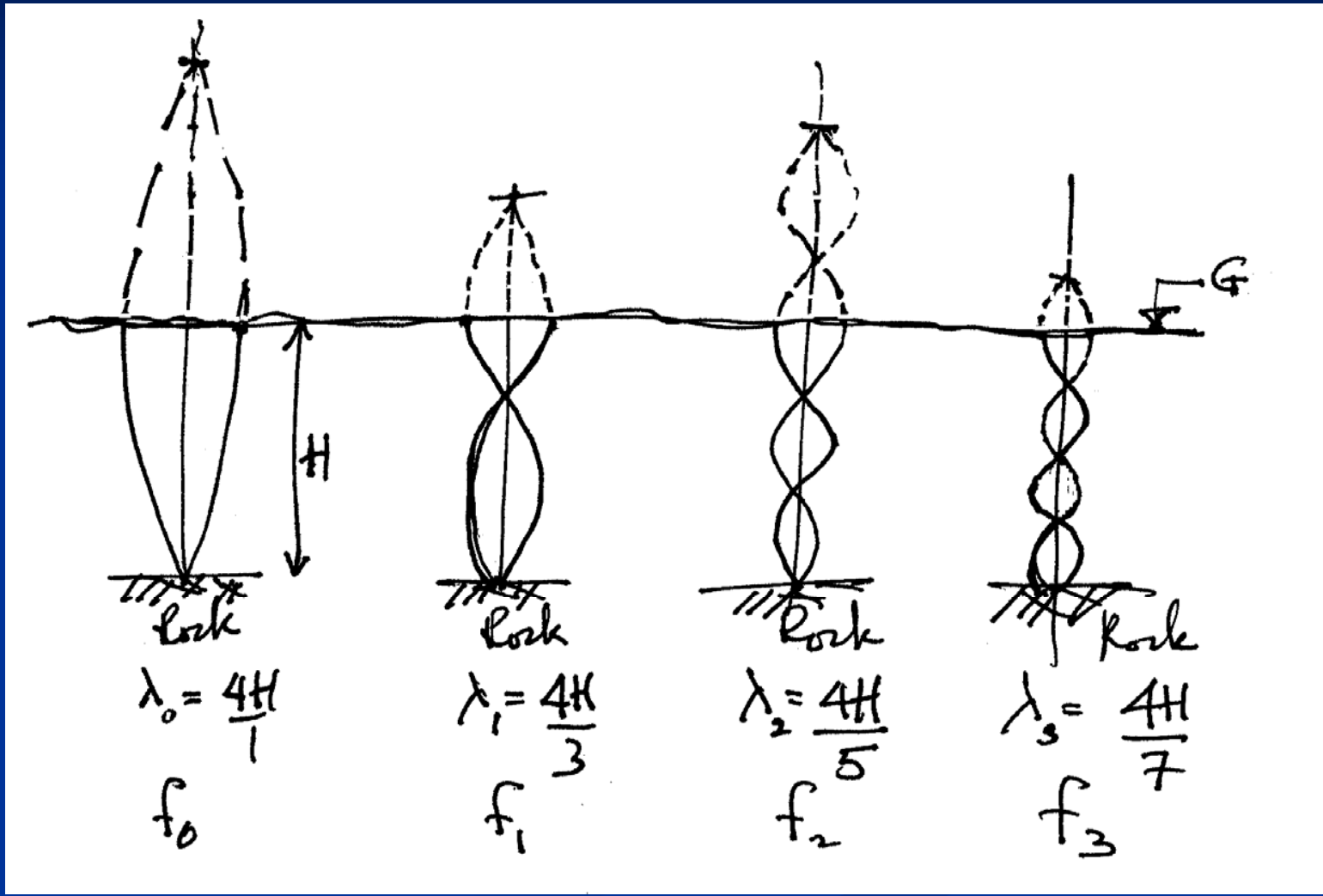


Fig. 4.2 Common types of elastic stress and strain. Cross-sections of bodies shown before strain (solid line) and after strain (dashed line). Directions of stress are shown by thick arrows. The related elastic moduli are defined. (a,b) Young's modulus, E, and Poisson's ratio, σ; (c) shear (or rigidity) modulus, μ; (d) bulk modulus, K; application of uniform pressure shown by thick arrows around the body. Poisson's ratio is a measure of the relative deformation of the body in two perpendicular directions. F denotes the force acting on a cross-sectional area A.

Relationship between Shear Wave Velocity and Modal Frequency Response in soil profiles as an Elastic Half Space

$T = \lambda/Vs$ (s)

$f = 1/T$ (cyc/s)



T = Period (s), λ= Wavelength (m), Vs = shear wave velocity (m/s), f = frequency (cycles/s)

Modal Periods/Frequencies for Soft Soil Profile Site Class F: Thickness H= 20 m

		Vs = 150 m/s		Vs = 60 m/s	
Mode	λ (m)	T (s)	f	T (s)	f
0	80.0	0.53	1.88	1.33	0.75
1	26.7	0.18	5.55	0.44	2.27
2	16.0	0.11	9.10	0.27	3.70
3	11.4	0.08	12.5	0.19	5.26

1615.2 Site-specific procedure for determining ground motion accelerations

- A site-specific study shall account for the regional seismicity and geology;
- the expected recurrence rates and maximum magnitudes of events on known faults and source zones;
- the location of the site with respect to these;
- near source effects if any and the characteristics of subsurface site conditions.

1615.2.1 Probabilistic Maximum Considered Earthquake (MCE)

- Where site-specific procedures are used as required or permitted in Section 1615, the MCE ground motion shall be taken as the motion represented by an acceleration response spectrum having a 2% probability of exceedance in 50 years;
- **Exception:** where the spectral response ordinates at 0.2 or 1.0 second of a 5% damped spectrum (2% in 50 year) exceed the corresponding ordinates of the **deterministic limit of Section 1615.2.2** the MCE ground motion shall be taken as the lesser of the probabilistic ground motion or **deterministic ground motion of Section 1615.2.3**
- but shall not be taken as less than the **deterministic limit ground motion of Section 1615.2.2**

1615.2.2 Deterministic Limit on Maximum Considered Earthquake (MCE)

- The deterministic limit for the MCE ground motion shall be the response spectrum determined in accordance with Figure 1615.2.2, where site coefficients, Fa and Fv are determined from Section 1615.1.2 (Tables as per normal method) with the values of mapped spectral response accelerations;
- Ss = 1.5 g
- S1 = 0.6 g

1615.2.3 Deterministic Maximum Considered Earthquake (MCE)

- The deterministic MCE ground motion response spectrum shall be calculated as 150% of the median spectral response accelerations, S_{aM} , at all periods resulting from a **characteristic earthquake on any known active fault within the region.**

- **characteristic earthquake on any known active fault within the region?**

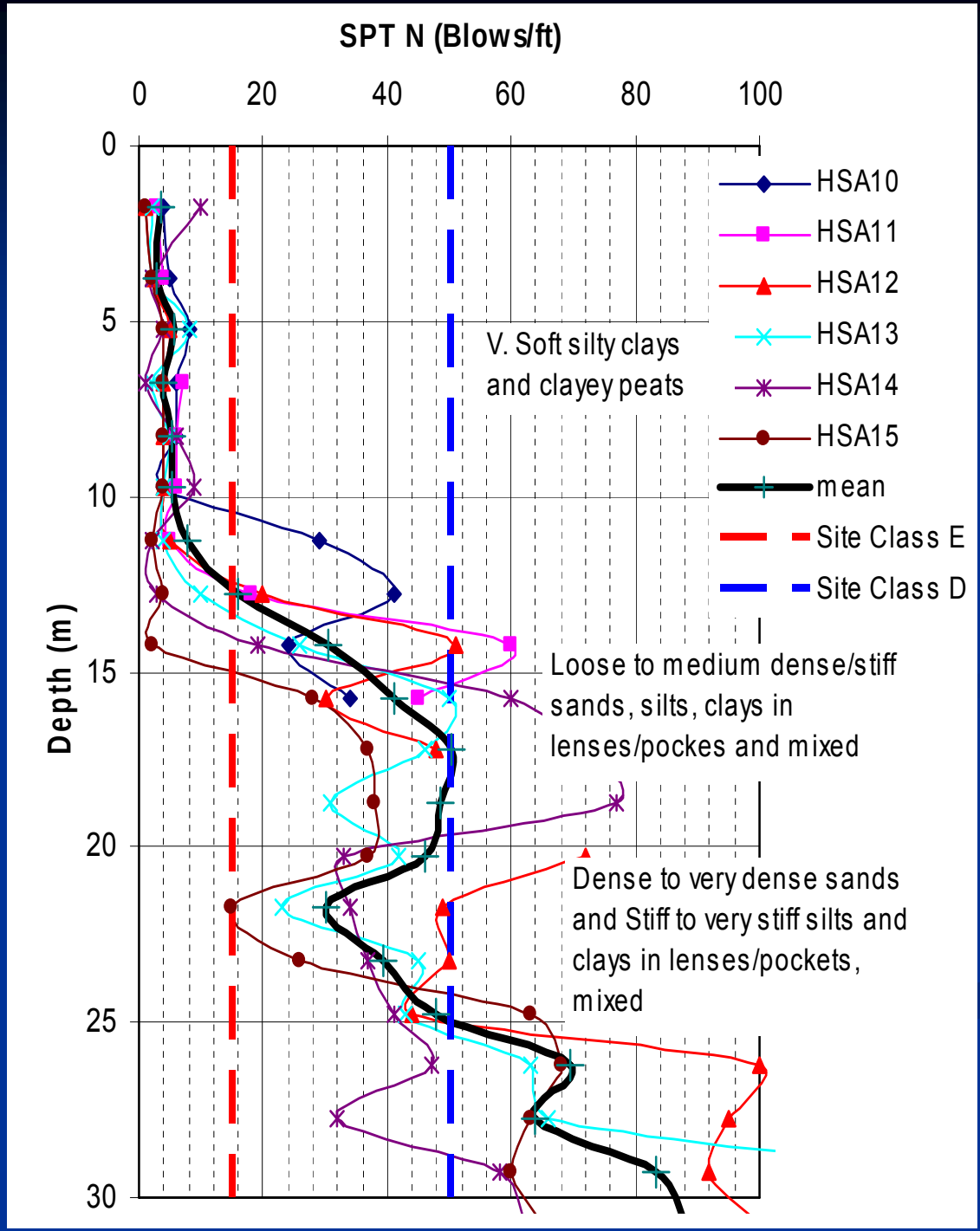
1615.2.3 Characteristic earthquake on any known active fault within the region Maximum Considered Earthquake (MCE): Demands:

- Accurate Tectonic Mapping and Monitoring to define active faults and mechanisms
- Strong Motion Measurements?

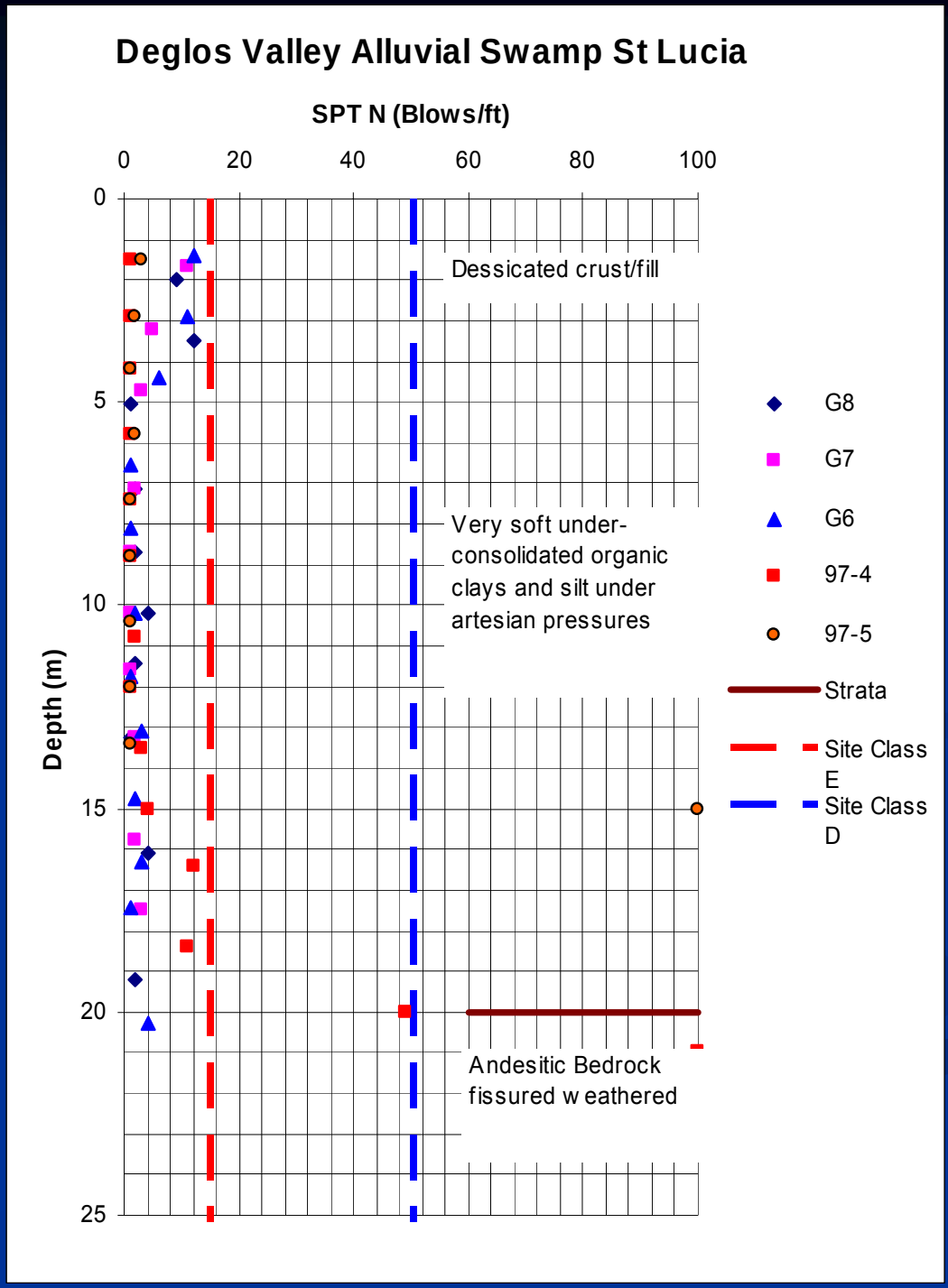
1615.2.3 Site-specific evaluation of Four Sites in the Eastern Caribbean: Site Classes E & F

- Beetham Highway Trinidad: Organic clay alluvium over dense sand
- Deglos Valley St Lucia: Organic clay alluvium over andesitic rock
- Melville Hall Dominica: Deeply weathered Ash over pyroclastic agglomerate
- St Vincent South: Deeply weathered Ash over pyroclastic agglomerate

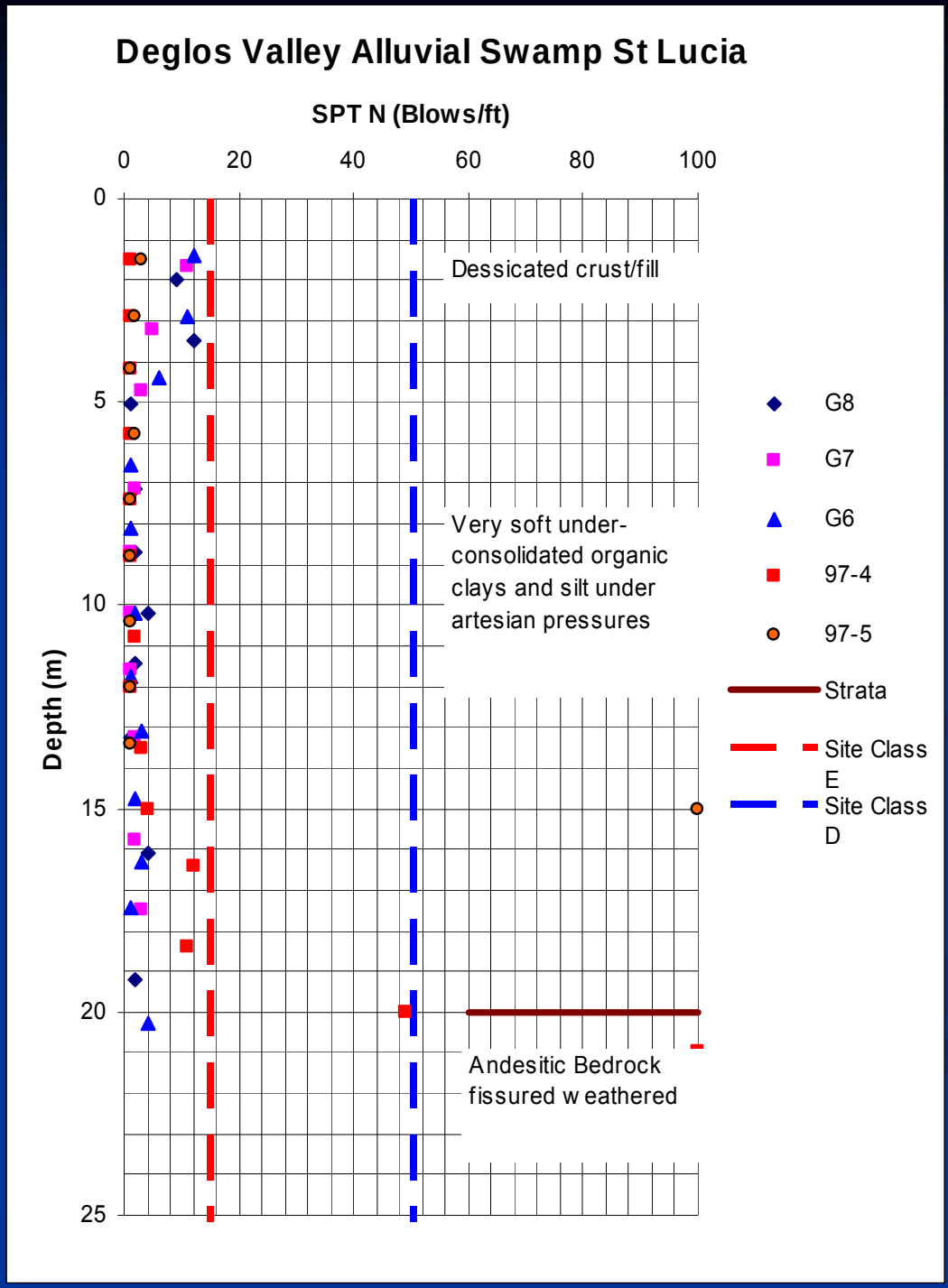
Beetham Swamp Trinidad: Site Class F



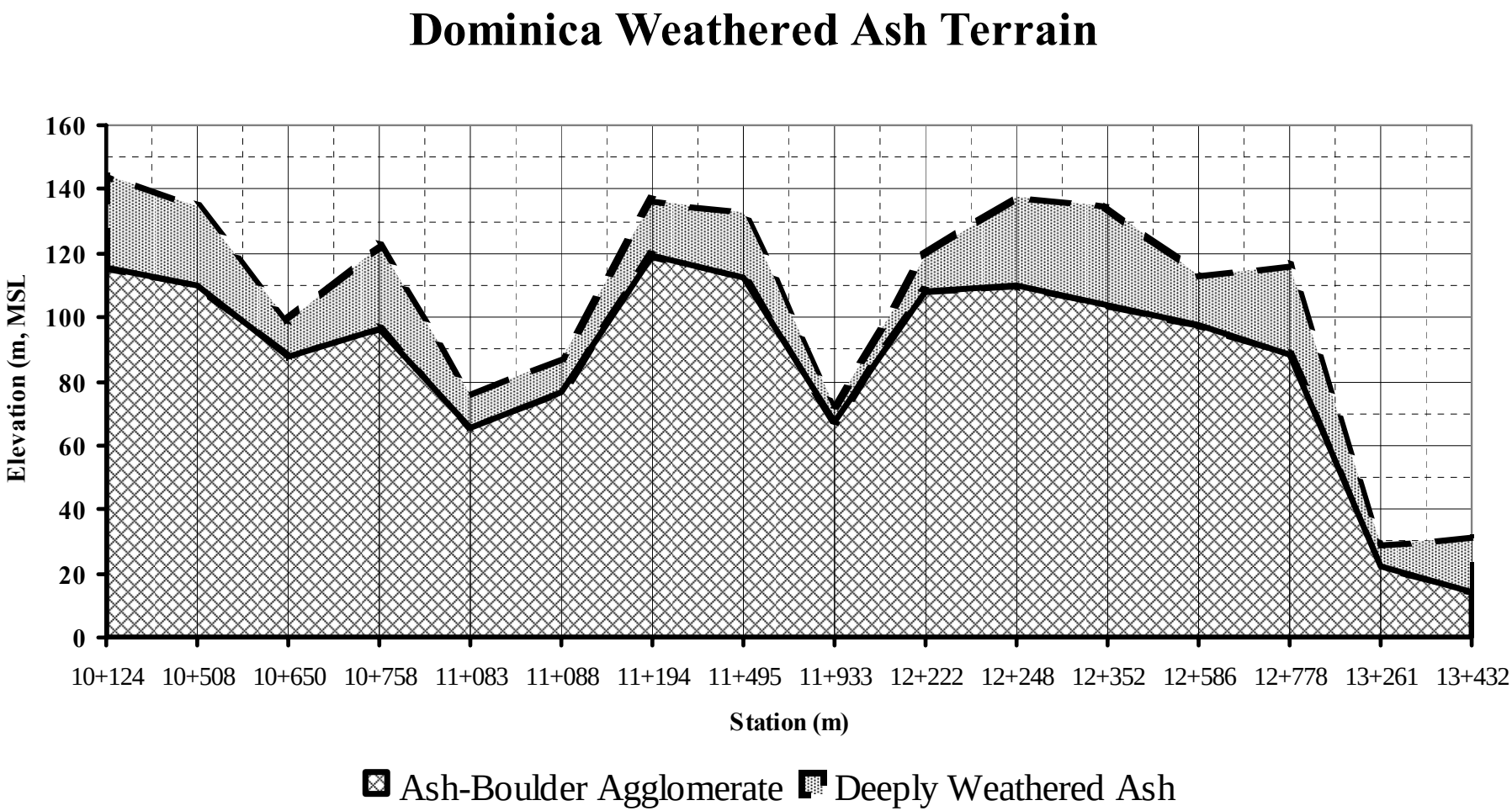
Deglos Valley Alluvial Swamp St Lucia: Site Class F



Deglos Valley Alluvial Swamp St Lucia: Site Class F



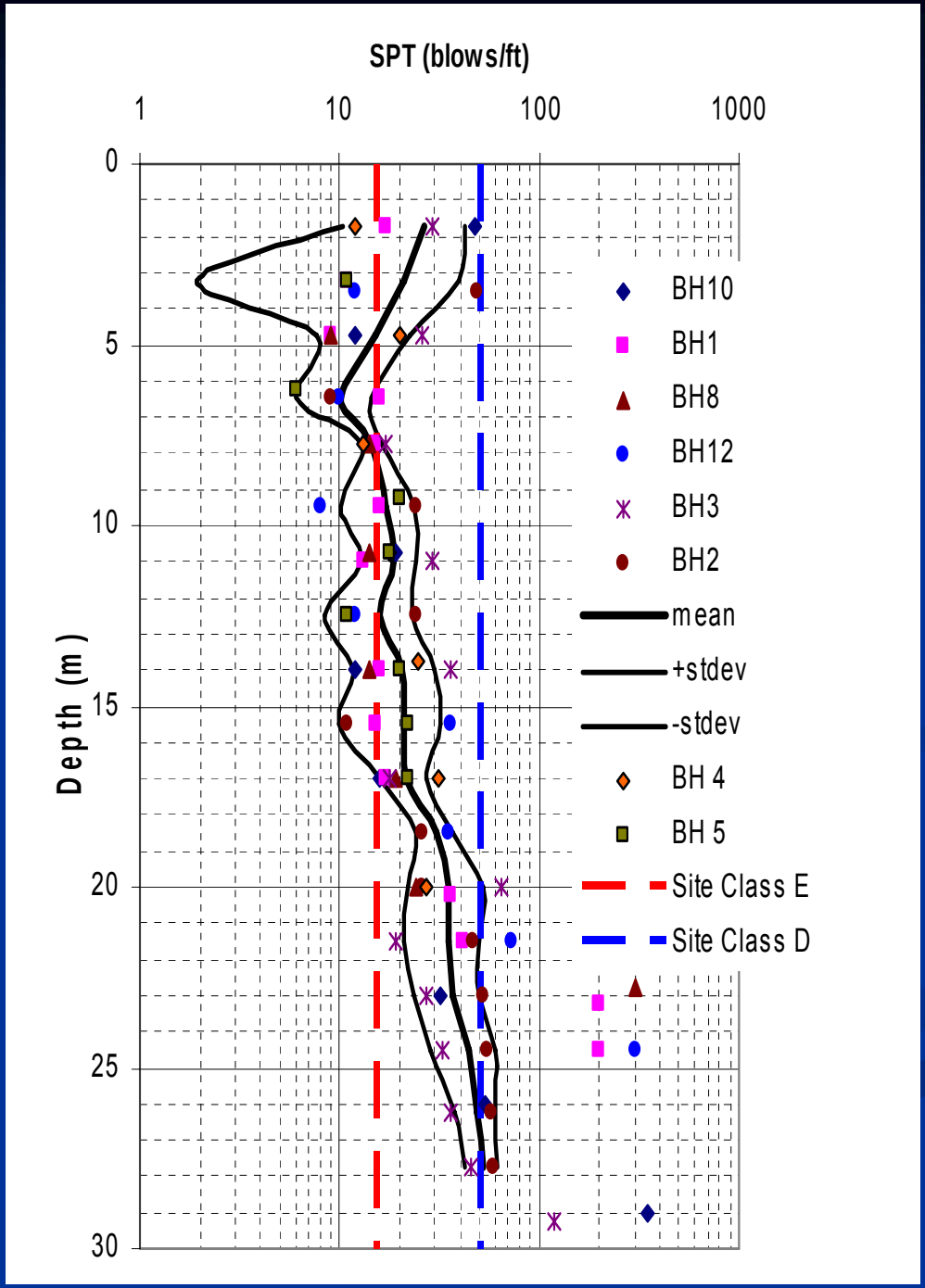
Melville Hall Dominica: Deeply weathered ash over Boulder Agglomerate



Melville Hall Dominica:

Deeply weathered ash over Boulder Agglomerate:

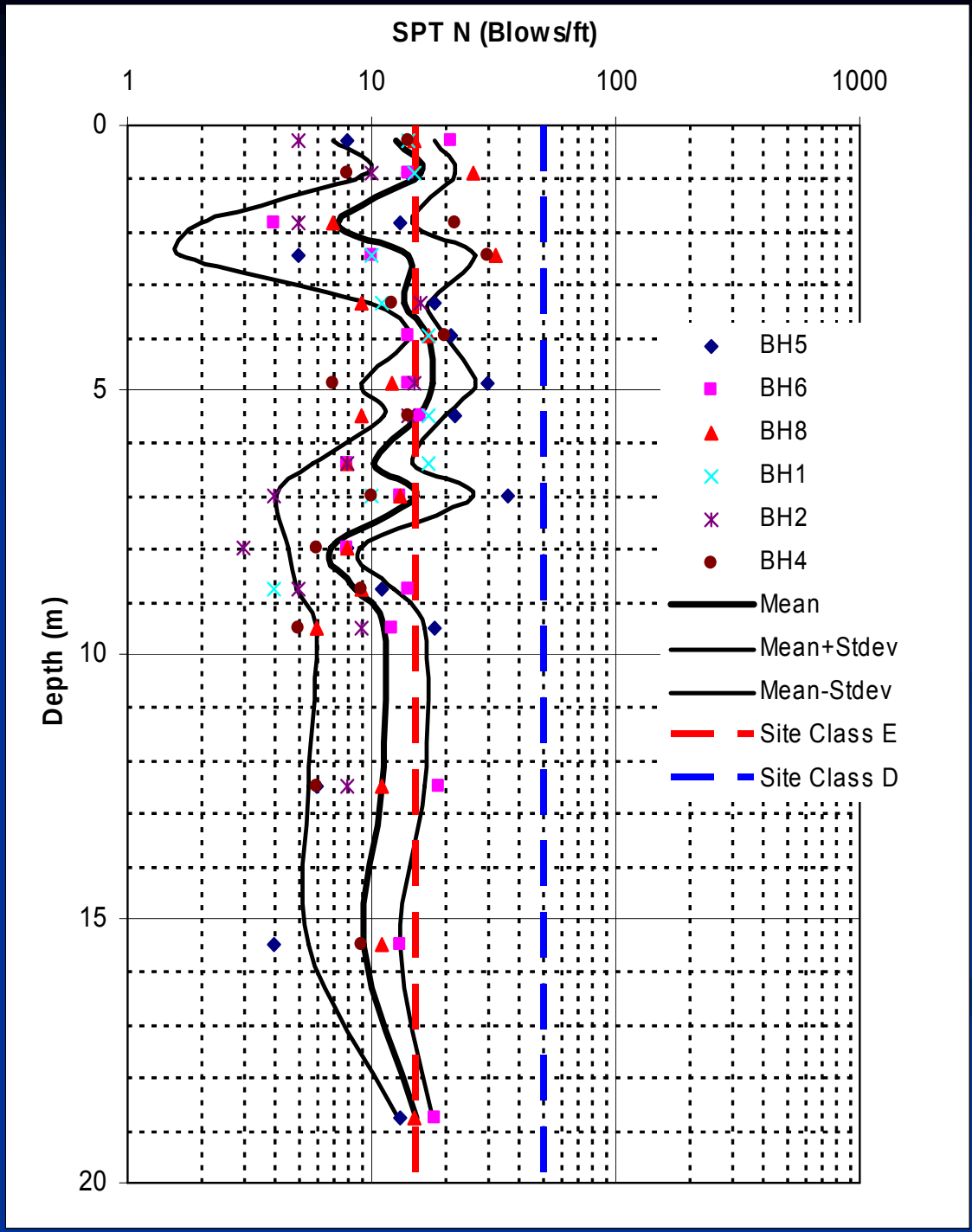
Site Class E/F



St Vincent South:

Deeply weathered ash over weathered andesites:

Site Class E/F



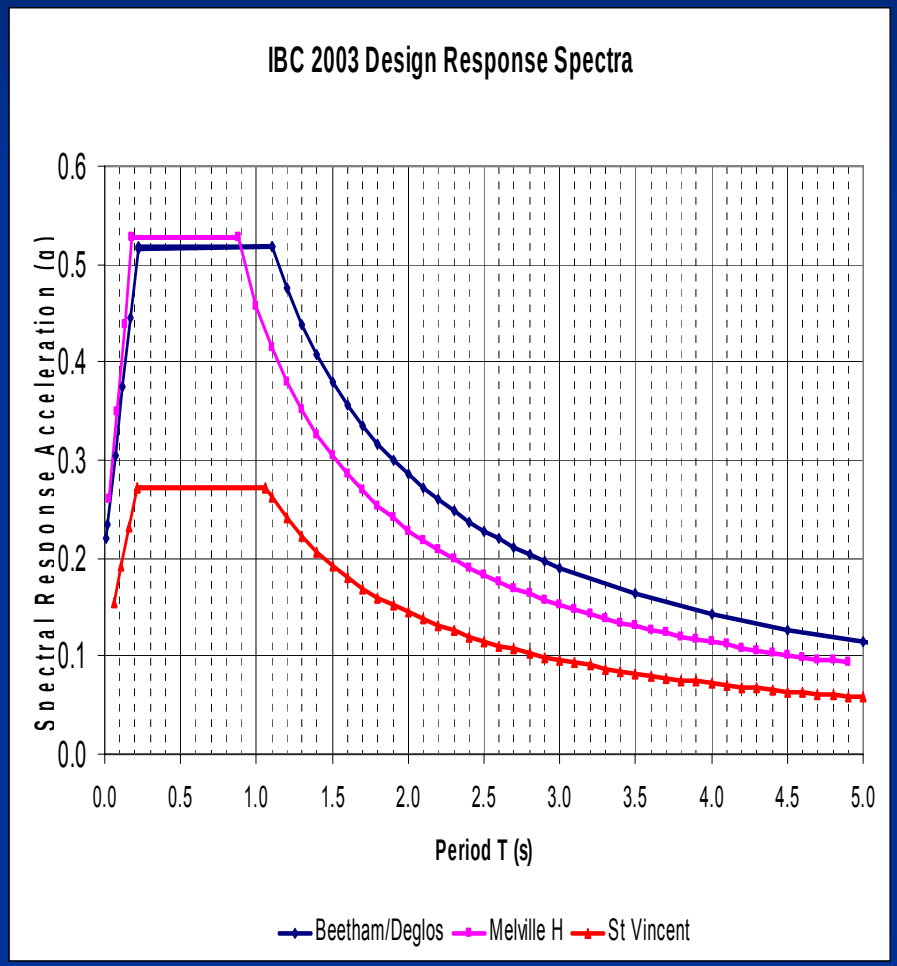
1615.2.3 Site-specific evaluation of Four Sites in the Eastern Caribbean: Site Classes E & F

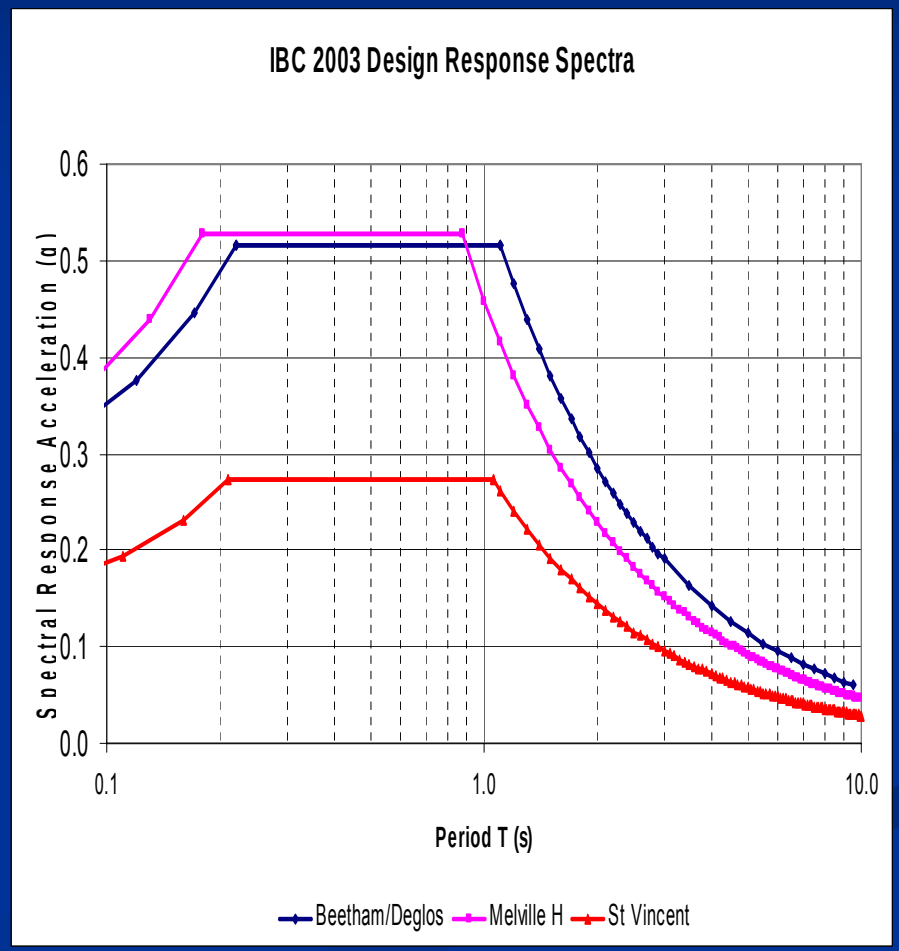
- Beetham Highway Trinidad: Organic clay alluvium over dense sand
- Deglos Valley St Lucia: Organic clay alluvium over andesitic rock
- Melville Hall Dominica: Deeply weathered Ash over pyroclastic agglomerate
- St Vincent South: Deeply weathered Ash over pyroclastic agglomerate

1615.2.3 Site-specific evaluation of Four Sites Eastern Caribbean: Assuming Site Class E

	Ss (gals)	S_1 (gals)	Fa	Fv	S_{MS}	S_{M1}	S_{DS}	S_{D1}	T_0 (secs)	T_S (secs)
Beetham	325	300	2.34	2.8	0.775	0.856	0.517	0.571	0.22	1.10
Deglos	325	300	2.34	2.8	0.775	0.856	0.517	0.571	0.22	1.10
Melville H	425	210	1.8	3.2	0.780	0.685	0.520	0.457	0.18	0.88
St Vincent	160	125	2.5	3.4	0.408	0.433	0.272	0.289	0.21	1.06

1615.2.3 IBC2003 Site-specific evaluation Eastern Caribbean: Site Classes E & F





1615.2.3 Site-specific evaluation of Site Classes F/E

- **characteristic earthquake on any known active fault within the region?**
- No?
- Then borrow some!
- ok

1615.2.3 Site-specific evaluation Earthquake borrowing criteria:

- a maximum acceleration of 0.3 g measured on bedrock or on very hard sediments
- a focal mechanism consistent with a subduction zone type event (Reverse Normal, Reverse Oblique faulting)
- shallow to intermediate deep focal depth (0< d < 100 km)
- a deep focal depth (> 100 km)
- a near source event (< 10 km from epicenter) of similar Magnitude to that expected.

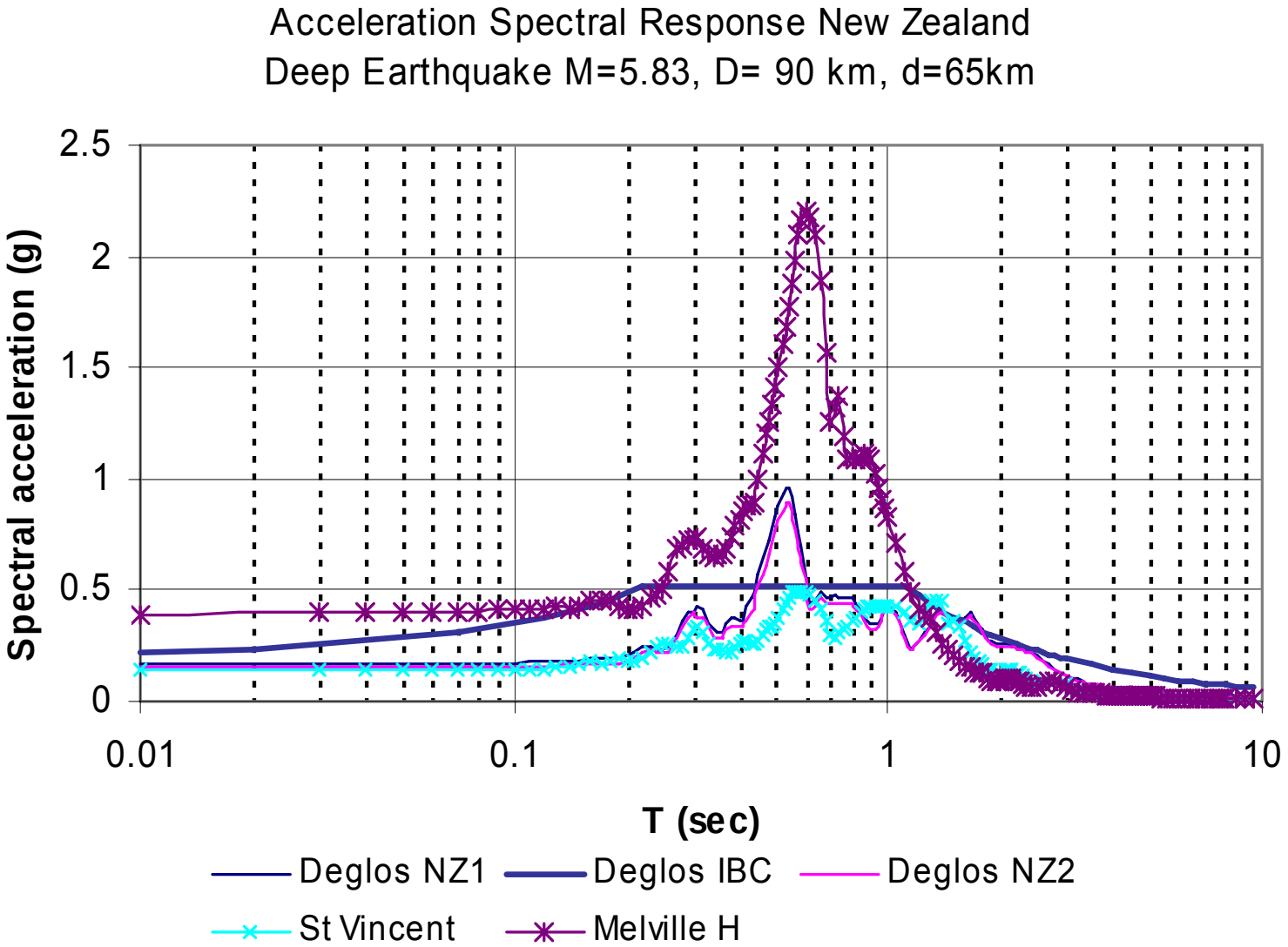
1615.2.3 Site-specific evaluation of Four Sites in the Eastern Caribbean: Site Classes E & F

- Loma Prieta Earthquake California :
- Northridge Earthquake California:
- Whittier Narrows Earthquake
- Chi Chi Earthquake China
- New Zealand Earthquakes (deep 90 km)

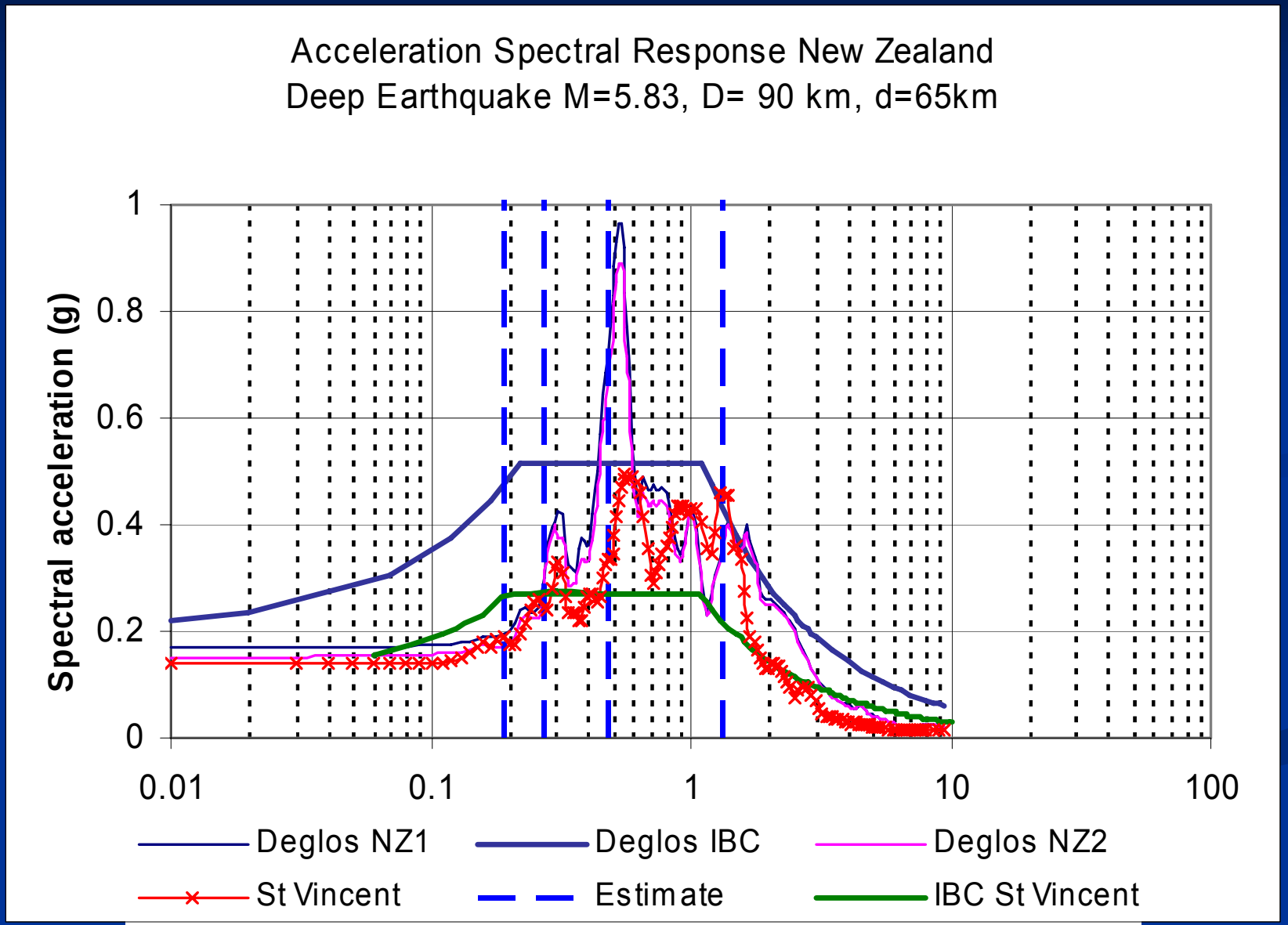
1615.2.3 Site-specific evaluation of Desihn Earthquakes Site Classes F/E

Earthquake	Date	M	Fault Mechanism	Station	Epicentral Distance (km)	g_{max}
Chi-Chi Taiwan	1999/09/20	7.6	Reverse Normal	TAP103	125.5	.177
Northridge	1994/01/17	6.7	Reverse Normal	San Gabriel E. Grand Ave.	41.7	.256
Loma Prieta	1998/10/18	6.9	Reverse Oblique	Gilroy Array #1	11.2	.209
Whittier Narrows	1987/10/01	6.0	Reverse Normal	San Gabriel E. Grand Ave.	9.0	.304
New Zealand		5.8			65	.699

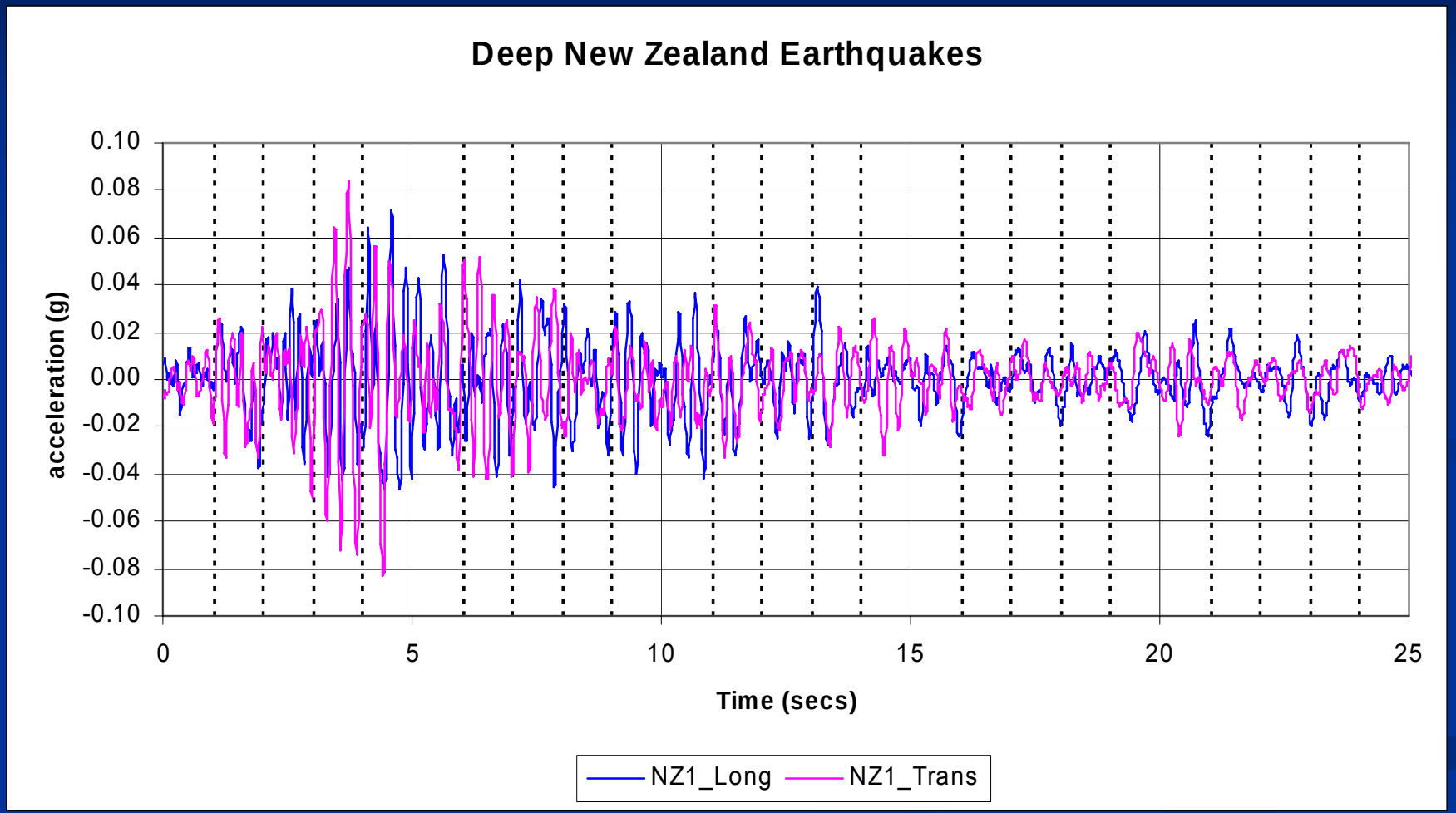
1615.2.3 Site-specific evaluation of Site Classes F/E



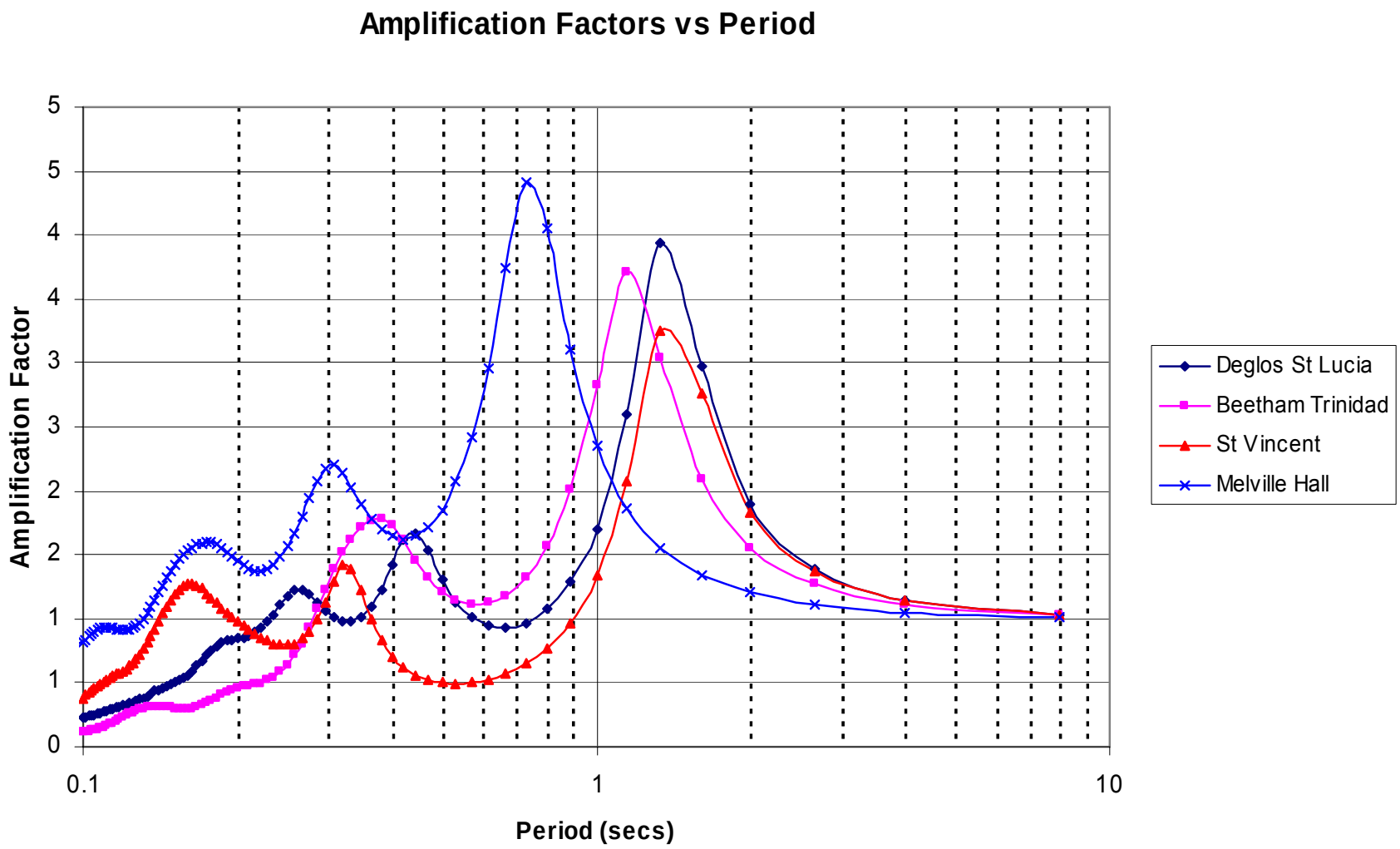
1615.2.3 Site-specific evaluation Site Classes F/E



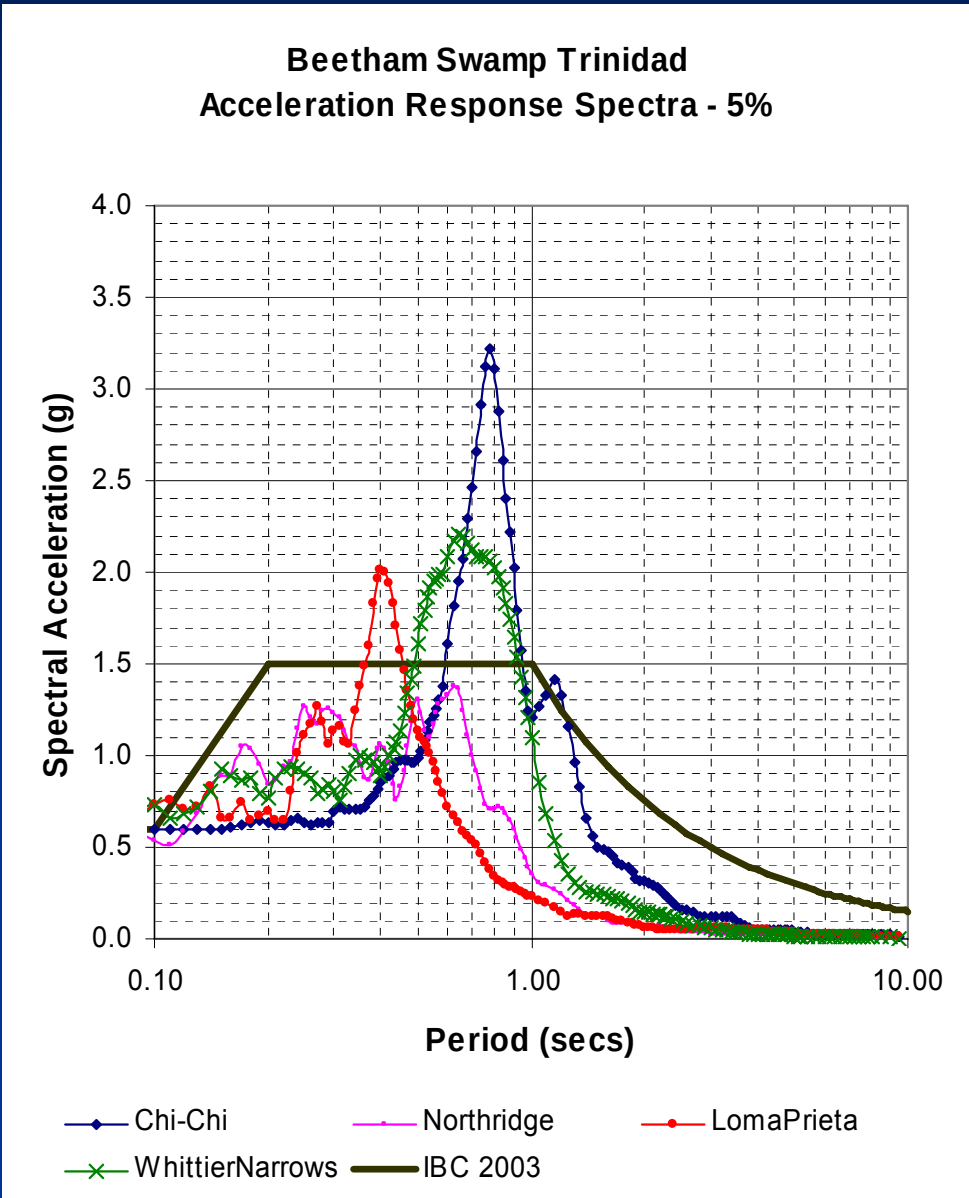
1615.2.3 Site-specific evaluation of Four Sites in



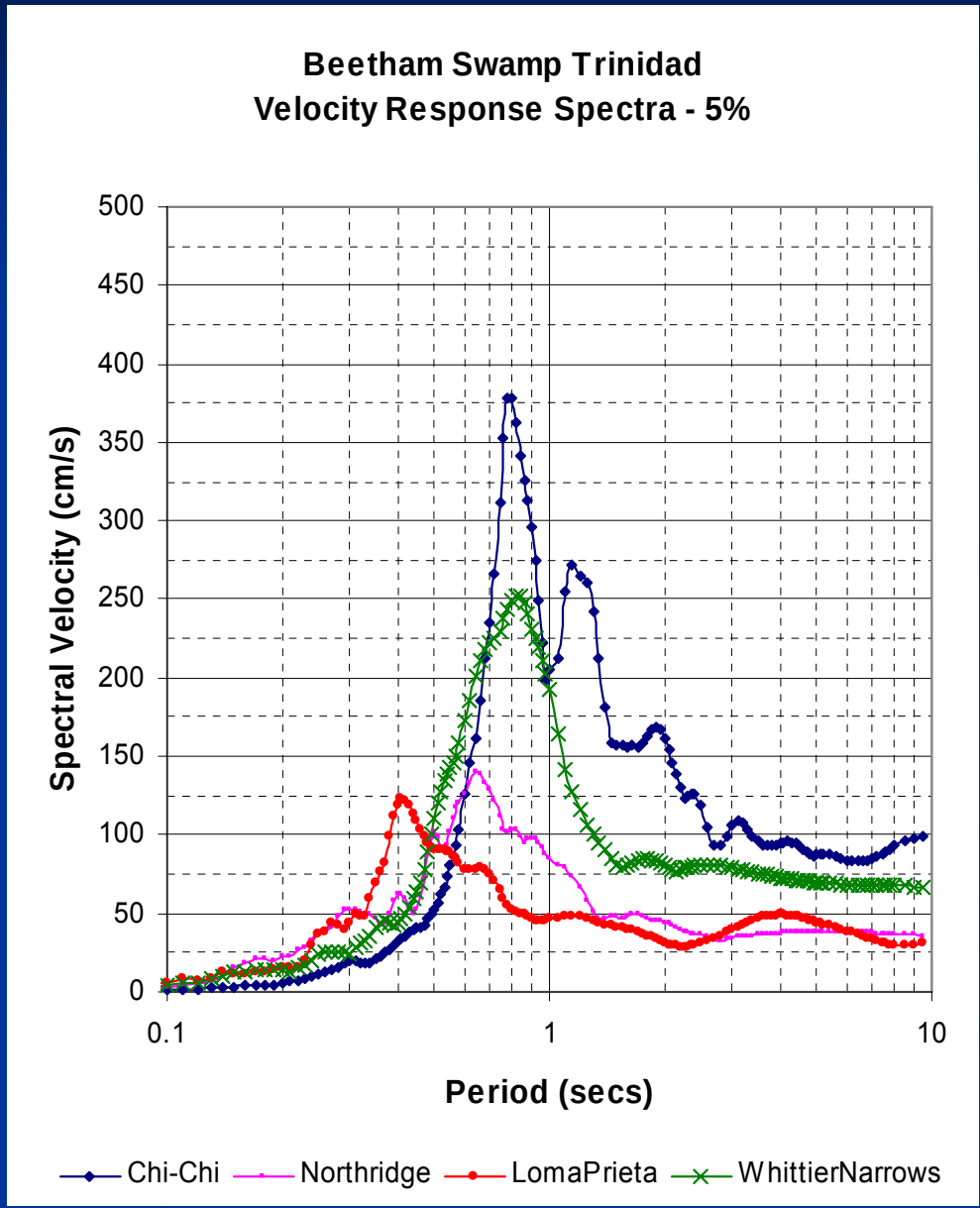
1615.2.3 Site-specific evaluation of Four Sites Eastern Caribbean: Site Classes E & F



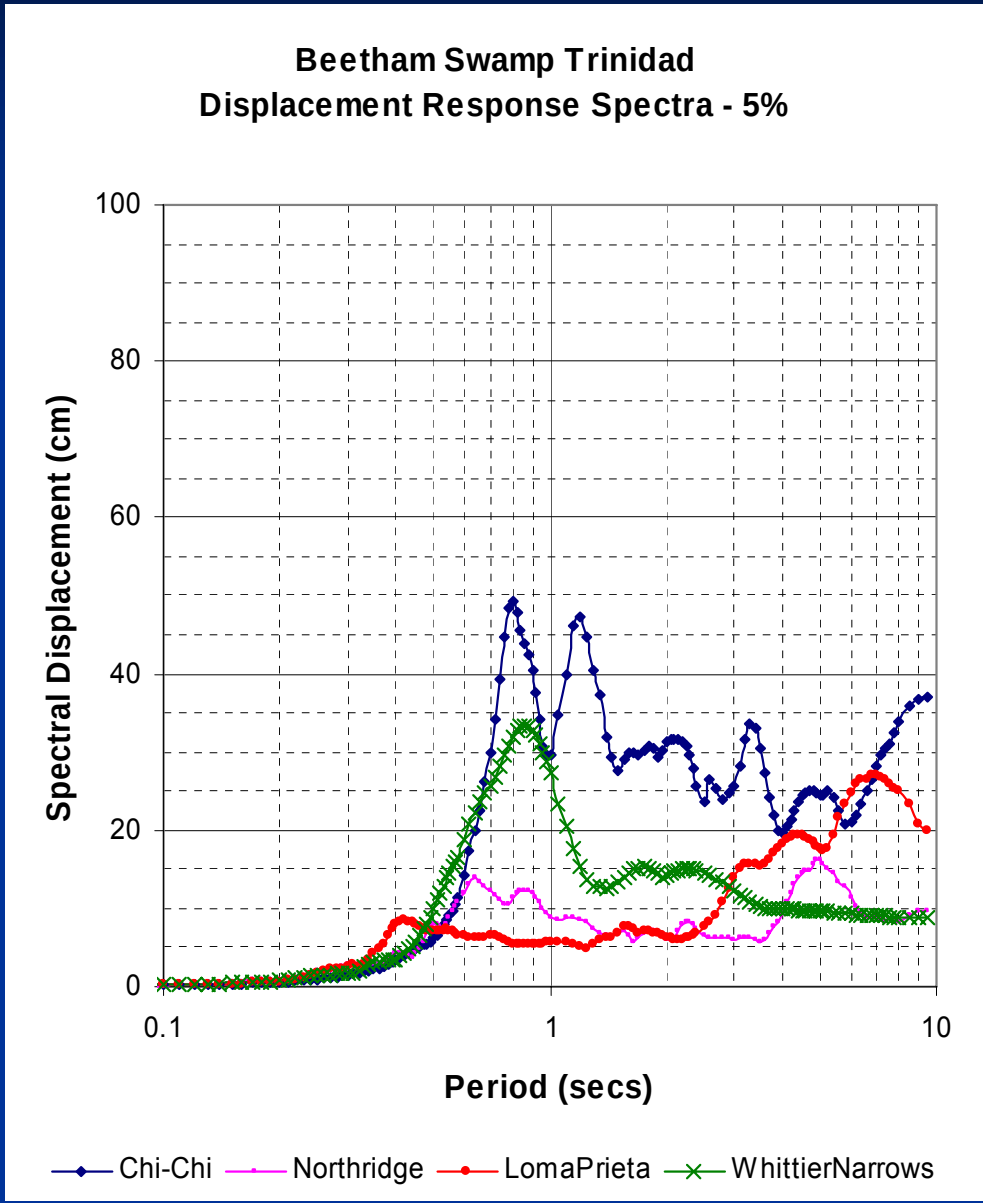
1615.2.3 Site-specific evaluation of Four Sites Eastern Caribbean: Site Classes E & F



1615.2.3 Site-specific evaluation
Eastern Caribbean: Site Classes E & F



1615.2.3 Site-specific evaluation
Eastern Caribbean: Site Classes E & F



1615.2.3 Site-specific evaluation of Site Classes F/E

- **characteristic earthquake on any known active fault within the region?**
- No?
- Then borrow some!
- Ok
- Thanks for your patience?
- Questions?