Urban Habitat Constructions Around Vesuvius

Environmental Risk and Engineering Challenges

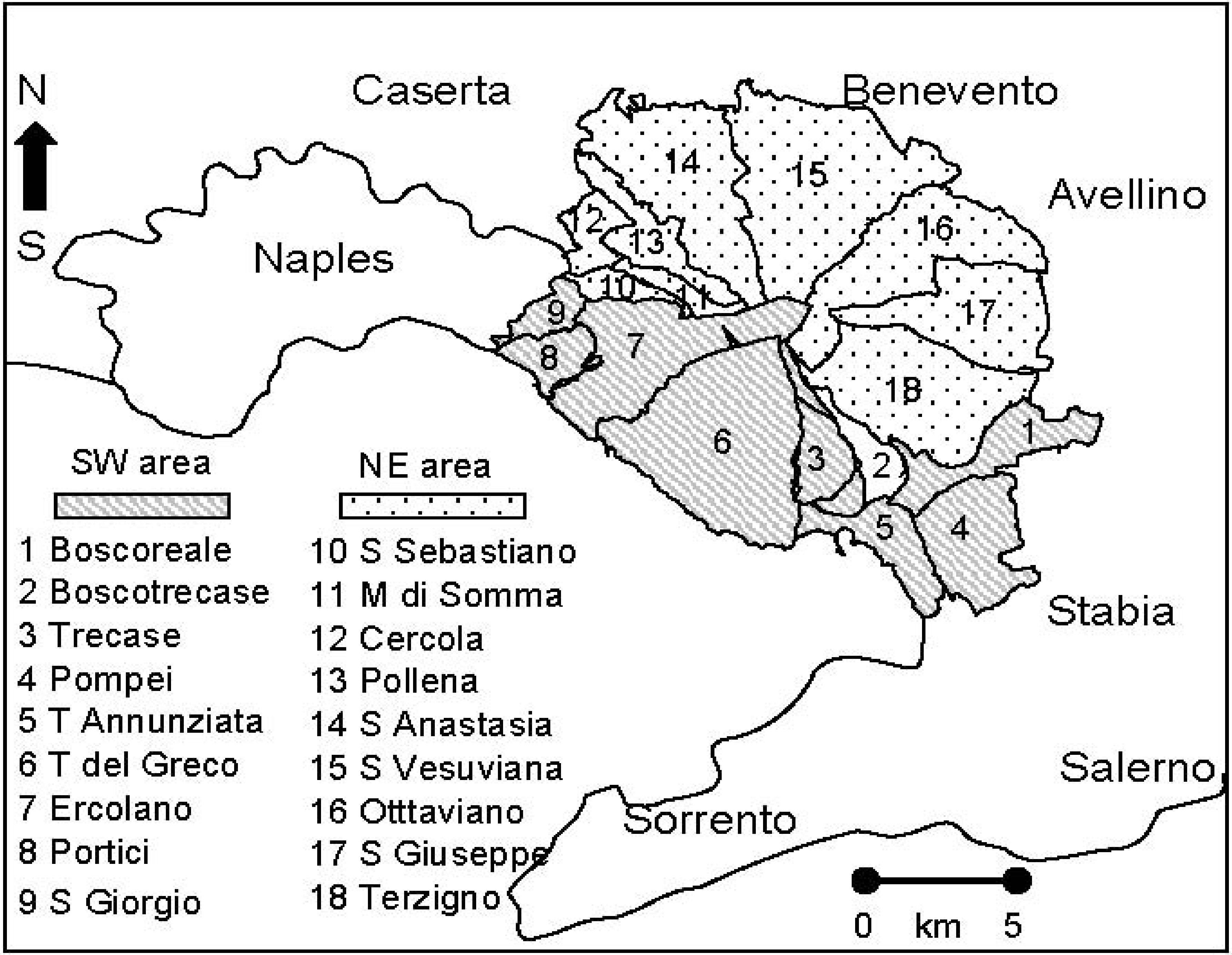
Flavio Dobran

GVES, Naples, Italy
Hofstra University, New York, U.S.A.

www.westnet.com/~dobran

Urban Habitat Constructions Under Catastrophic Events
Prague, 30-31 March 2007


VESUVIUS

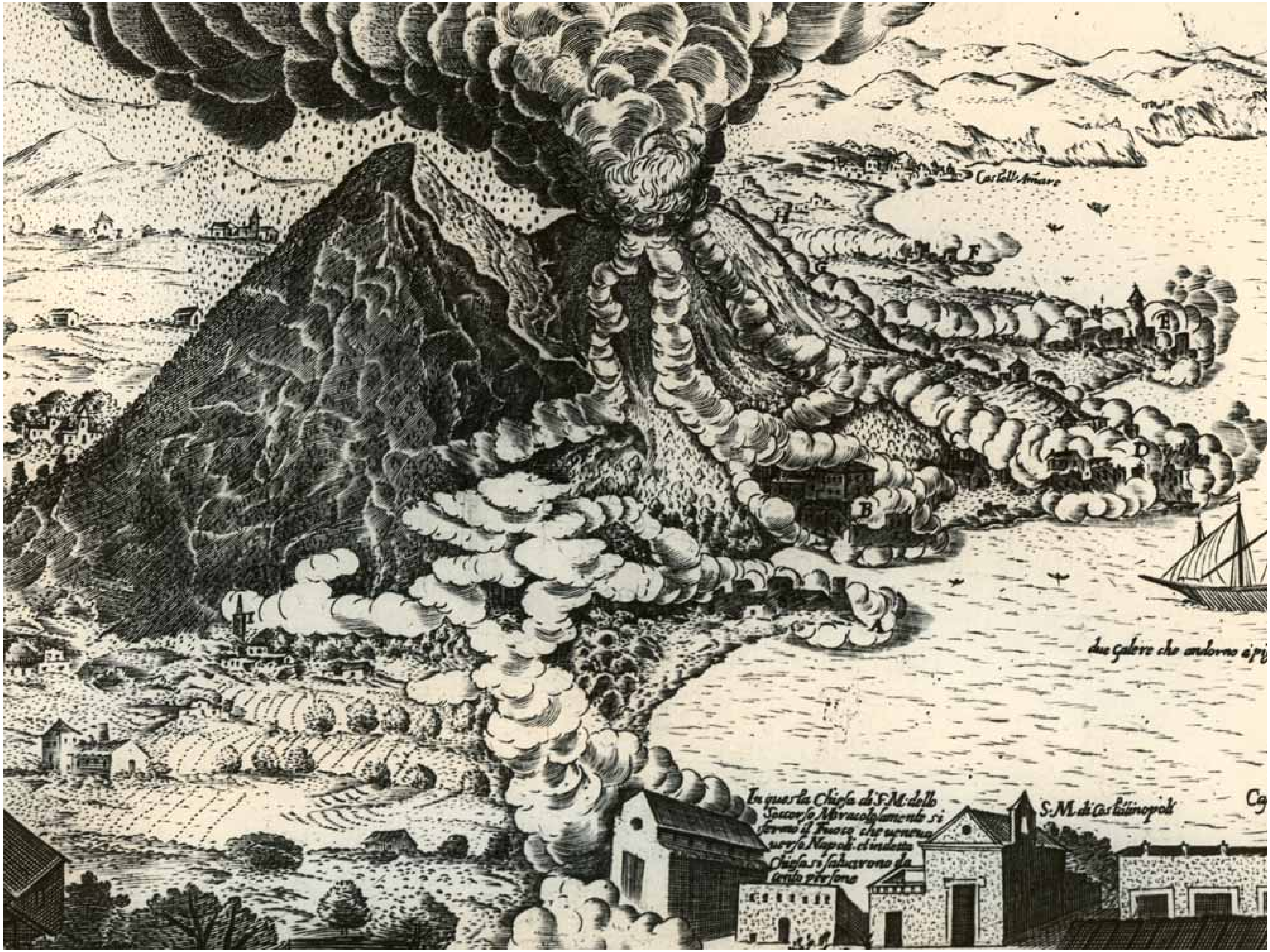

N
S
Caserta
Benevento
Avellino
Naples
Stabia
Salerno
Sorrento
14
15
16
17
18
12
13
10
11
9
8
7
6
3
2
1
5
4
SW area
NE area
1 Boscoreale
2 Boscotrecase
3 Trecase
4 Pompei
5 T Annunziata
6 T del Greco
7 Ercolano
8 Portici
9 S Giorgio
10 S Sebastiano
11 M di Somma
12 Cercola
13 Pollena
14 S Anastasia
15 S Vesuviana
16 Ottaviano
17 S Giuseppe
18 Terzigno
0 km 5

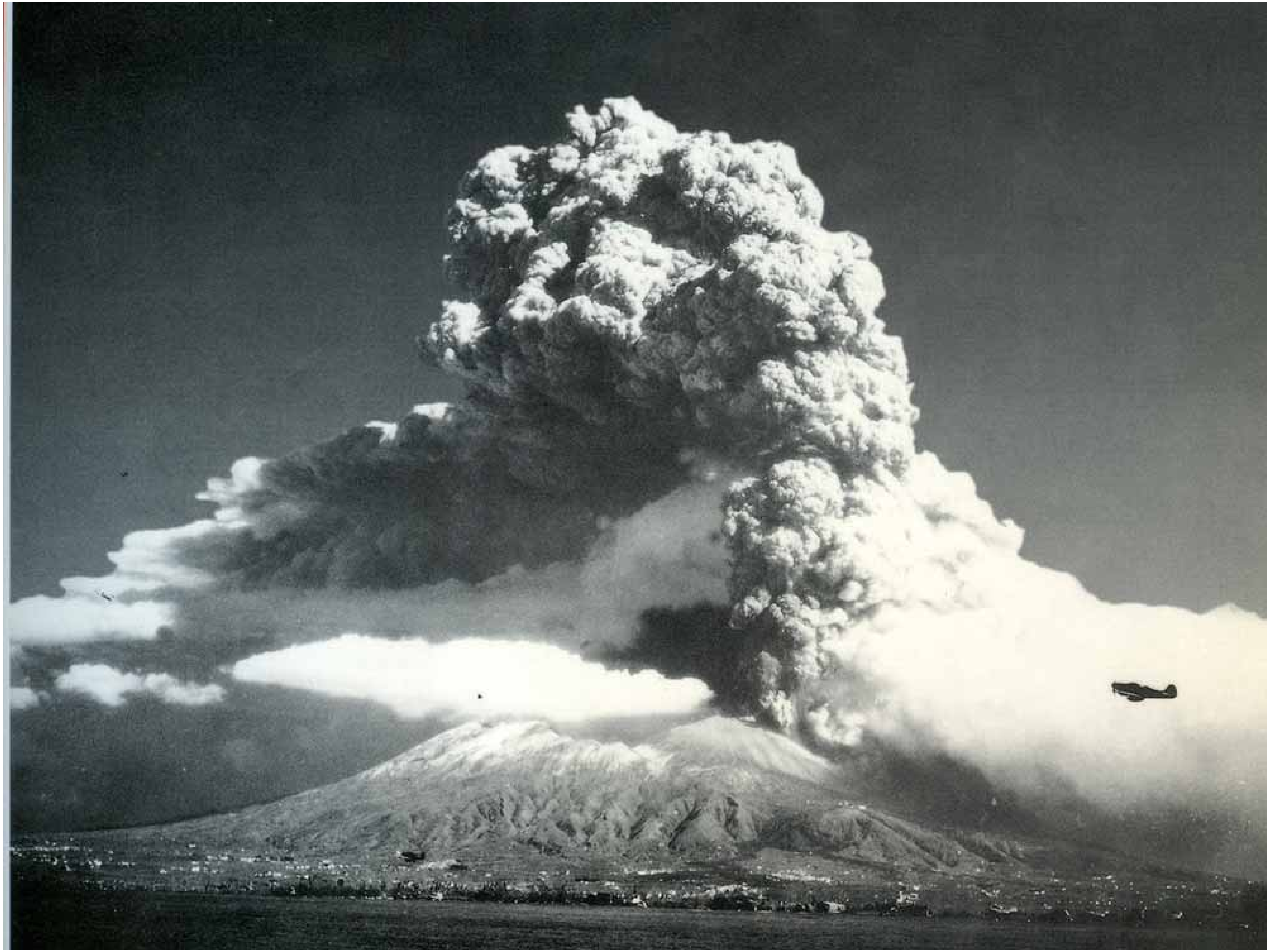
Eruption Deposits at Terzigno

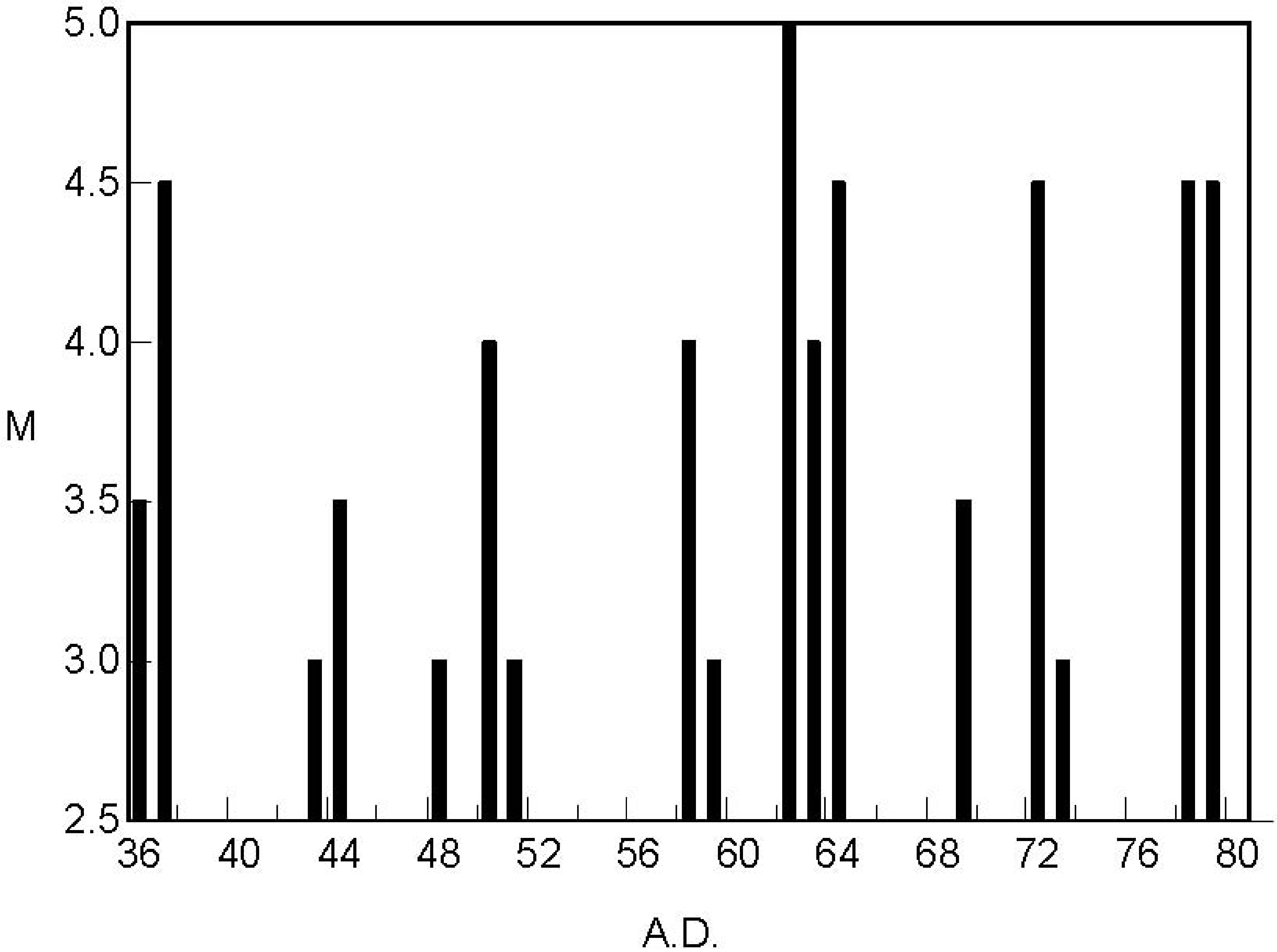
1631 (top)

79 A.D. (bottom)

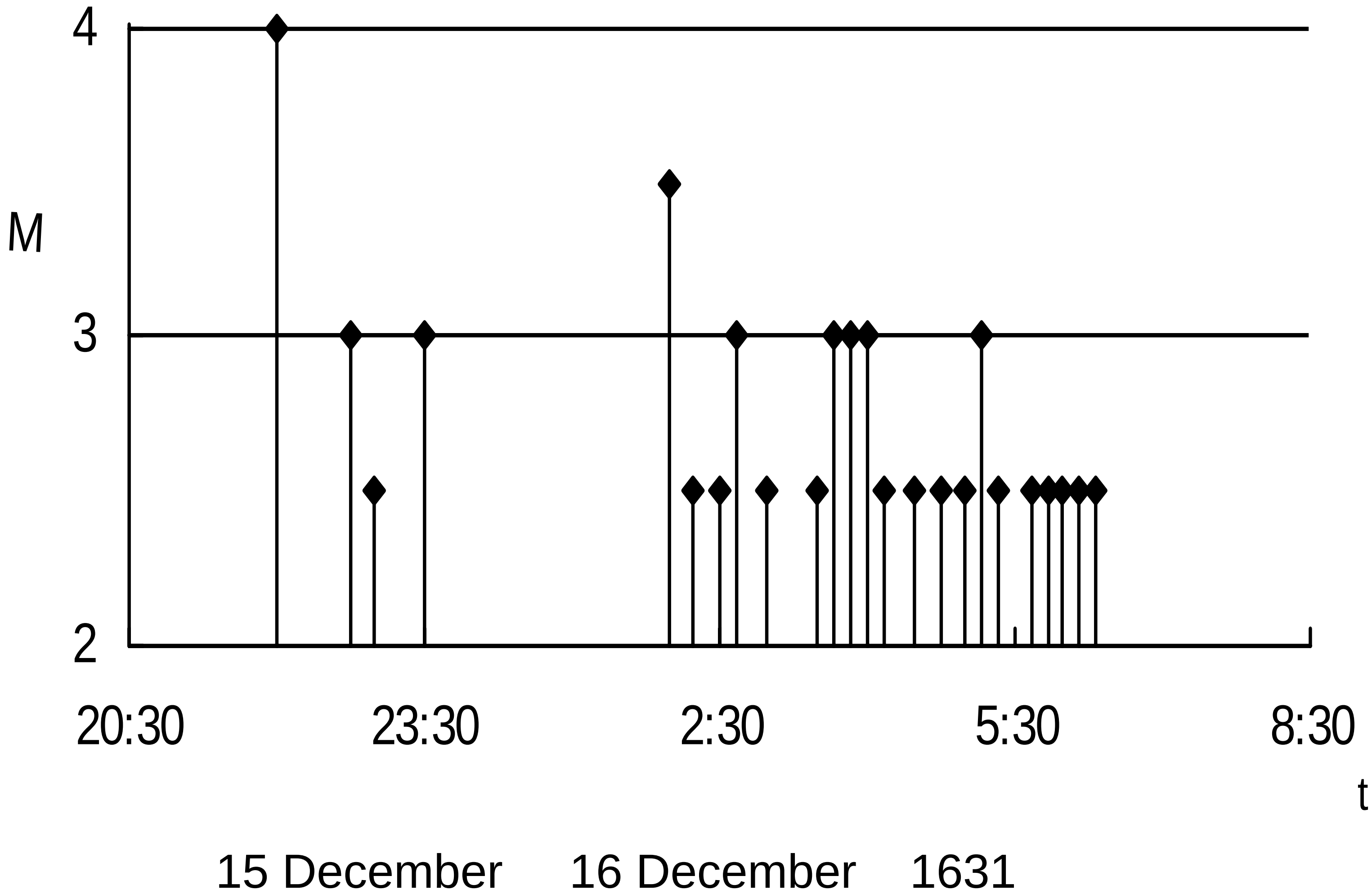
Eruption	Fall deposits			Pyroclastic surges and flows		
	Thickness m	Distance km	Direction	Thickness m	Distance km	Direction
Basal 17,000 y.B.P. plinian	2 0.2	4.5 22	N NE	3.5	4	N
Greenish 15,000 y.B.P. plinian	1 0.4	4.5 9	N N	15 2	4.5 9	N N
Lagno Amendolare 11,000 y.B.P. plinian	2 1	4 20	NW E–NE	Absent		
Ottaviano 8000 y.B.P. plinian 22 km, 3 km^3	4 3 1.5 0.5	5 10 20 30	N–NE N–NE N–NE N-NE	10 3.5 0.5 0.1	4.5 7 3.5 20	N NE NE NE
Avellino 3750 y.B.P. plinian 36 km, 4 km^3	0.8 1 0.6 0.1 1	6 15 30 40 3.5	E–NE E–NE E–NE E–NE NE	6 2 1 0.5 0.2	8 12 15 6 20	NW NW NW NE NW
Pompeii 79 A.D. plinian, 30 km, 3 km^3	14 4 2 1	5 8 20 40	W S–SE S–SE S–SE	15 10 2 3	5 8 8 10	W W–SW N–NE SE
Pollena 472 A.D. subplinian 20 km, ~ 1 km^3	1.3 1.2 0.9 0.3 0.7	5 8 20 30 10	NE NE NE NE NE	10–14 2 0.5	5 8 10	NW NW N–NE
1631 A.D. subplinian 20 km ~ 1 km^3	0.7 0.5 0.3 0.2 0.1	8 10 15 20 25	E–NE E–NE E–NE E–NE E–NE	0.3 0.2 0.1 4	5 10 15 7	E–NE E–NE E–NE S


Castell'Amare
due Galere che andorno a pi
In questa Chiesa di S. M. dello Soccorso Miracolosamente si fermo il Fuoco che veniua uerso Napoli et in detta Chiesa si saluarono da cento persone
S. M. di Costantinopoli

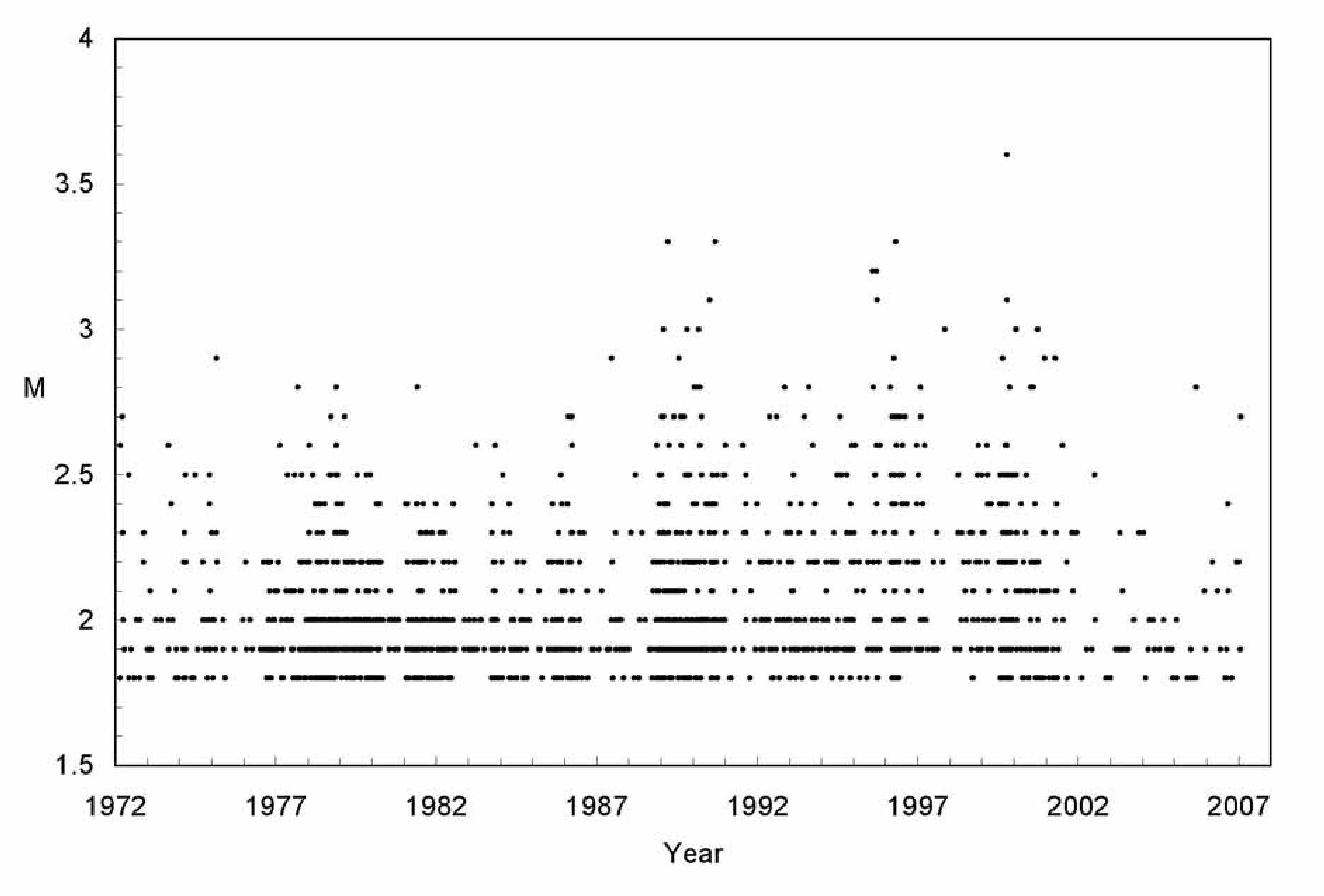




Earthquakes preceding the eruption in 79 A.D.

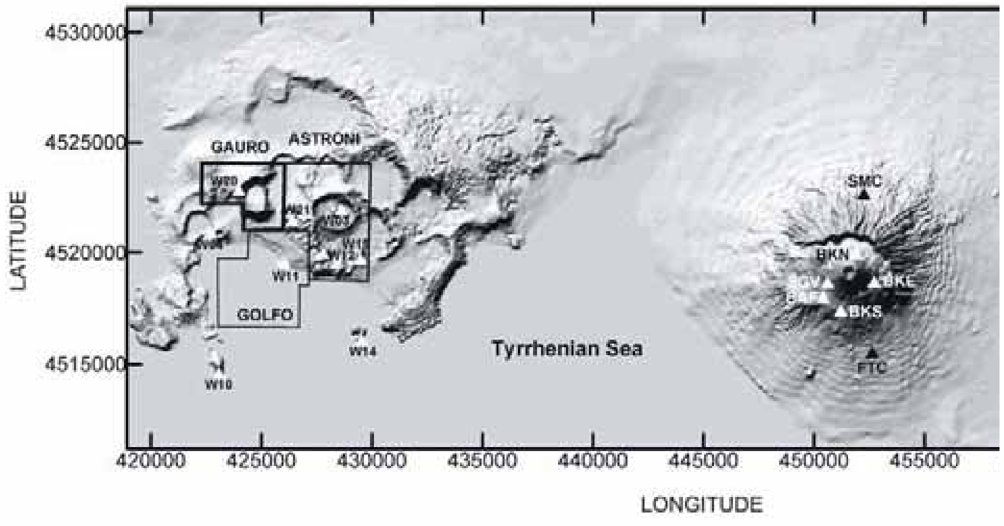


Earthquakes preceding the eruption in 1631

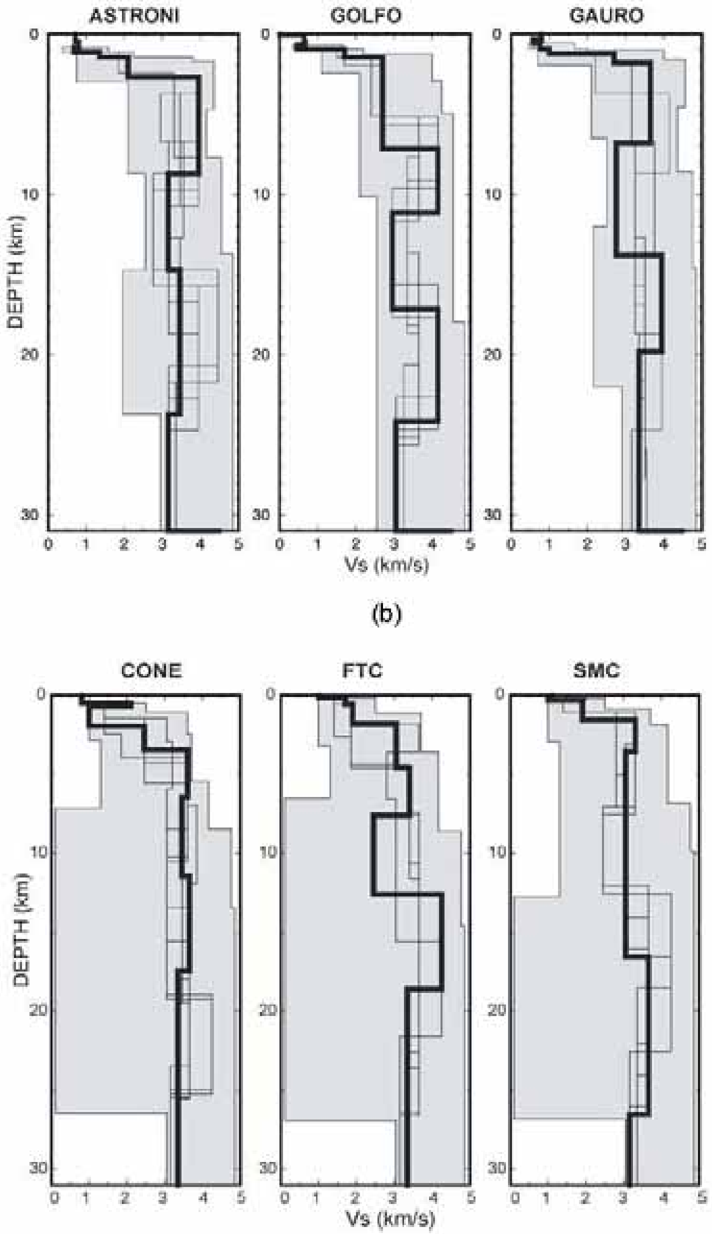


Recent earthquakes (OV catalogue)

Volcanic substructure: (low seismic velocities below 6 km)



(a)



(b)

(c)

Guidarelli et al. (2006)

Choices for the future

- Do nothing; wait for eruption and pray that 600,000 people can be evacuated in 1-2 days
- Force the Vesuvius area into socio-economic decline by empowering organized crime and involuntary exodus
- Construct sustainable habitats for Vesuvians

Risk analysis procedure

- Risk
  - What can happen?
  - How likely is that to happen?
  - If it happens, what are the consequences?
- Risk includes
  - All possible scenarios S_i
  - Likelihood of each scenario L_i
  - Consequences of *i*th scenario X_i

$$R = (S_i, L_i, X_i)_{complete}$$

- Bayes Theorem

  - Tells us how much our confidence change when we learn new evidence

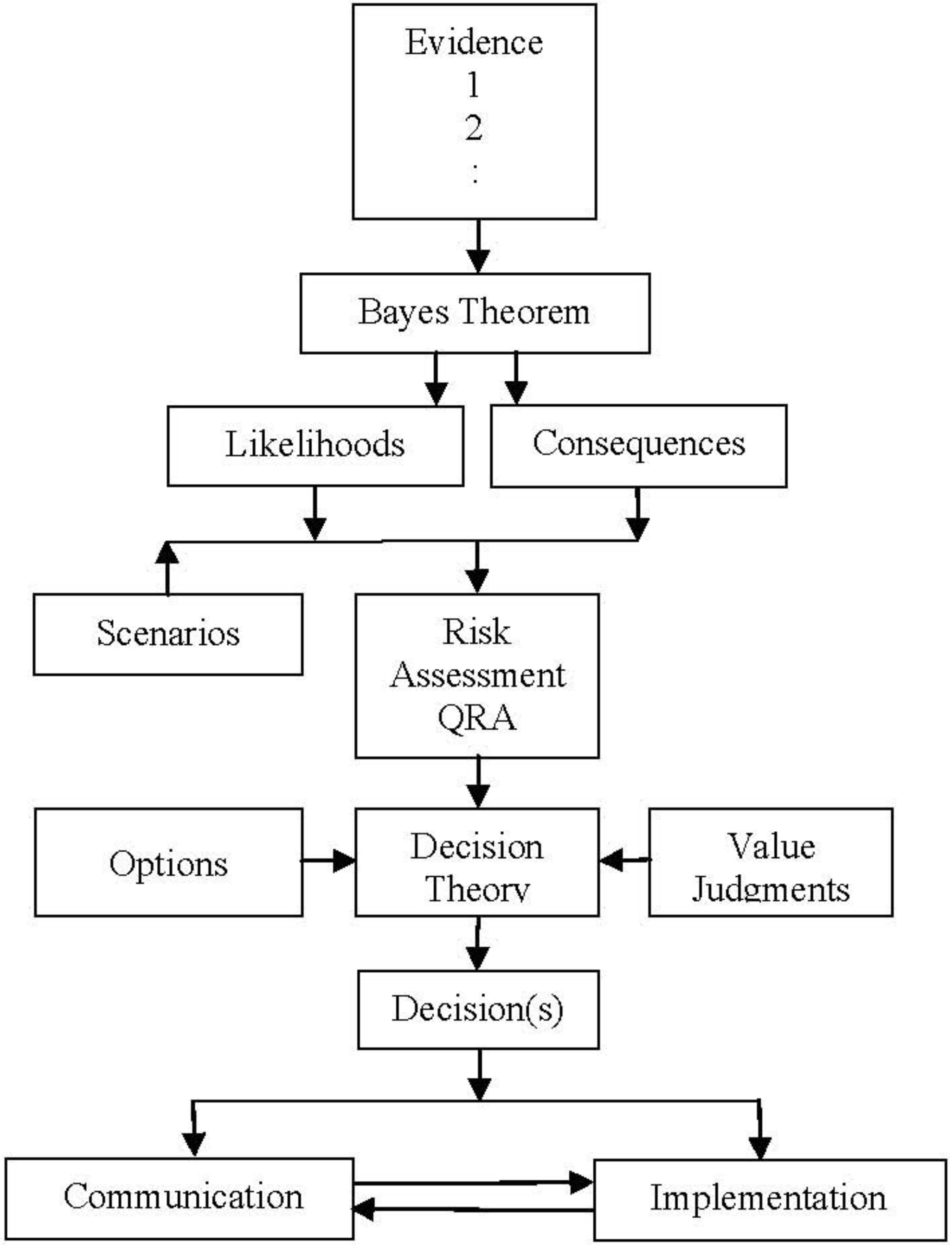
  - If A is the proposition and E the evidence relevant to this proposition

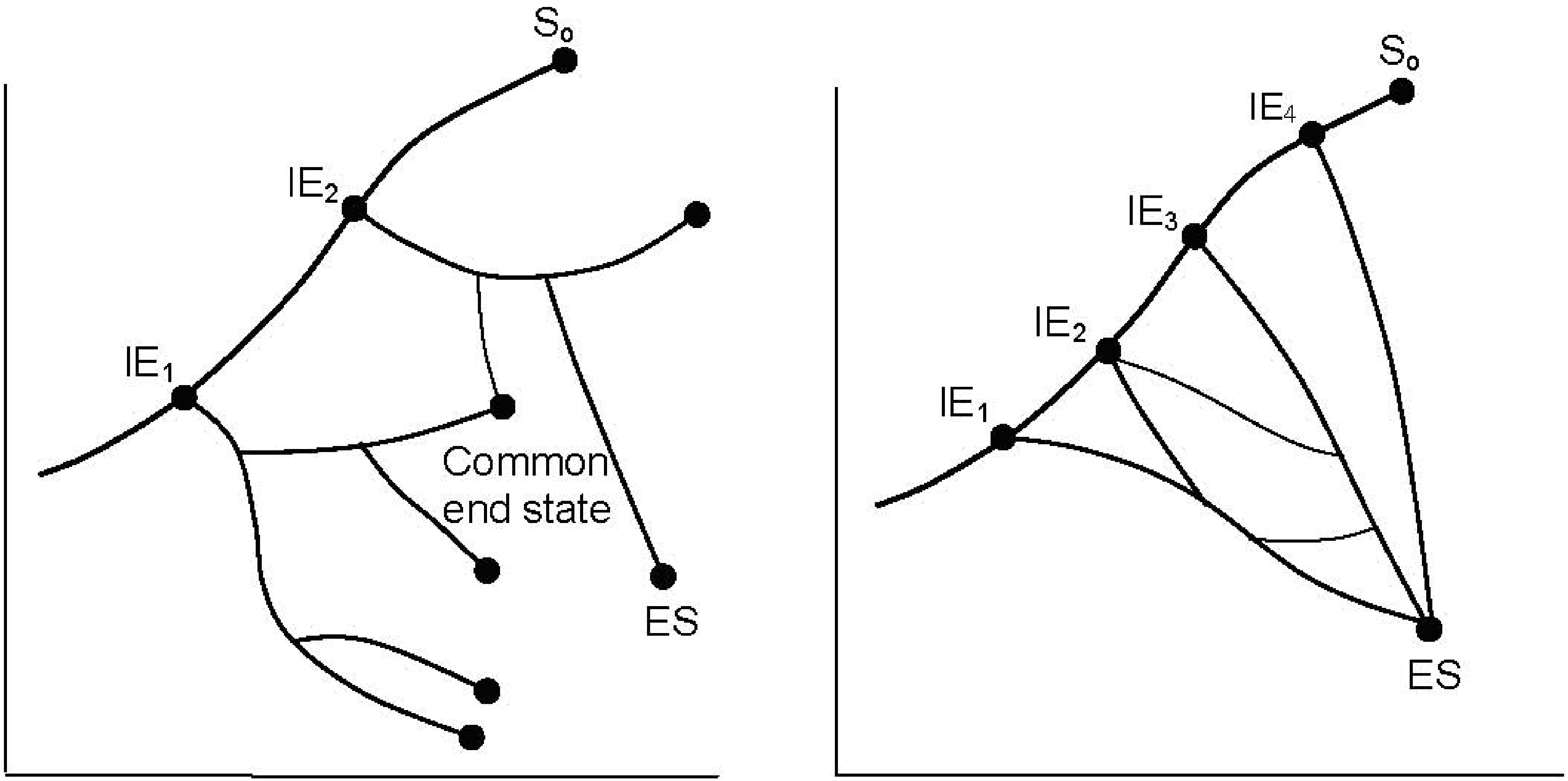
$$P(A/E) = P(A)\frac{P(E/A)}{P(E)}$$

posterior prior likelihood

- Quantitative Risk Analysis (QRA)
  - Maximize utility of decision d_i

$$u(d_i) = P(X / d_i) = \sum_{j=1}^{m} P(X / d_i @ A_j) P(A_j / d_i)$$


Evidence
1
2
:
Bayes Theorem
Likelihoods
Consequences
Scenarios
Risk
Assessment
QRA
Options
Decision
Theory
Value
Judgments
Decision(s)
Communication
Implementation



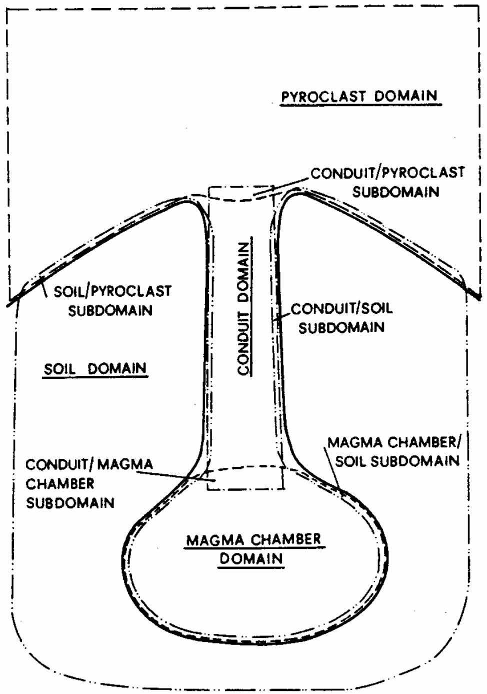
Scenario ‘event trees’

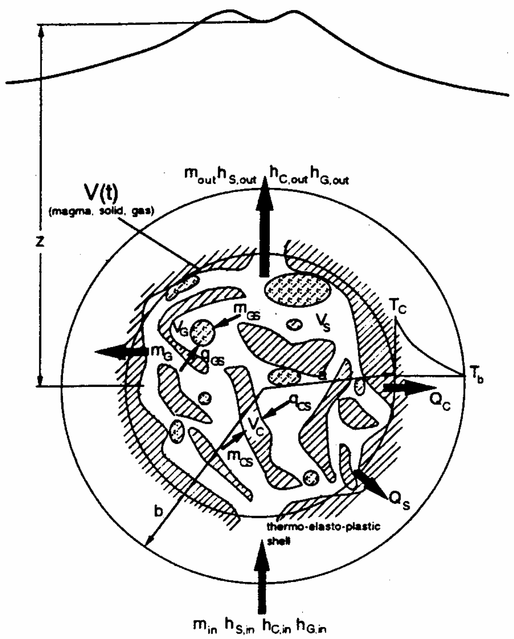
IS – initial state, ES – end state

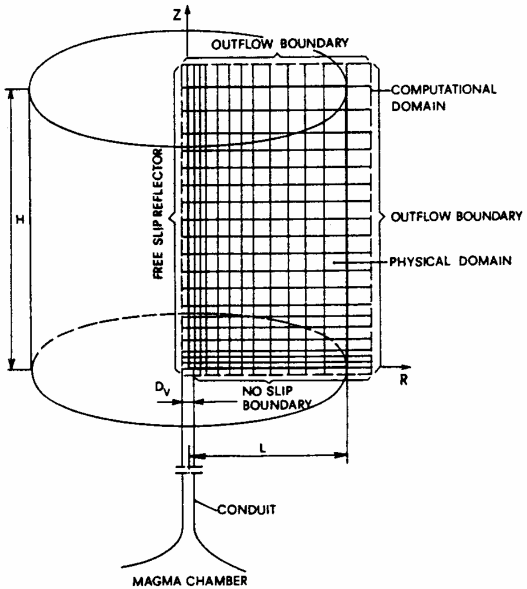
So – as planned scenario

Global Volcanic Simulator

- Physico-mathematical-computer model of entire volcanic system
- Determines scenarios and likelihoods of eruptions







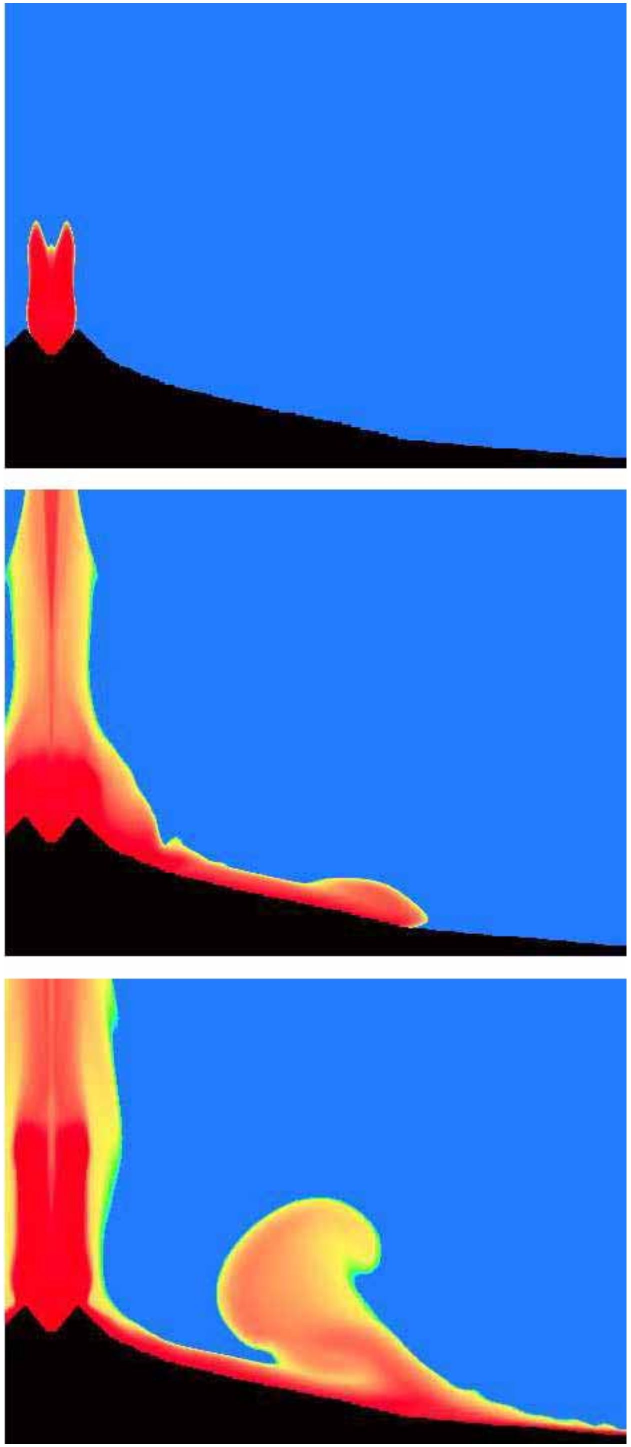
Law	Mass	Linear Momentum	Angular Momentum	Energy	Entropy
$\mathbf{\Psi}^{(\alpha\delta)}$	1	$\mathbf{v}^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{v}^{(\alpha\delta)}$	$\epsilon^{(\alpha\delta)}+\frac{1}{2}\mathbf{v}^{(\alpha\delta)}\cdot\mathbf{v}^{(\alpha\delta)}$	$s^{(\alpha\delta)}$
$\mathbf{J}^{(\alpha\delta)}$	0	$-\mathbf{T}^{(\alpha\delta)}$	$-\mathbf{r}\times\mathbf{T}^{(\alpha\delta)}$	$\mathbf{q}^{(\alpha\delta)}-\mathbf{T}^{(\alpha\delta)T}\mathbf{v}^{(\alpha\delta)}$	$\mathbf{h}^{(\alpha\delta)}$
$\mathbf{\Phi}^{(\alpha\delta)}$	0	$\mathbf{b}^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{b}^{(\alpha\delta)}$	$\mathbf{b}^{(\alpha\delta)}\cdot\mathbf{v}^{(\alpha\delta)}$	$R^{(\alpha\delta)}$
$\mathbf{B}^{(\alpha\delta)}$	0	0	0	$r^{(\alpha\delta)}$	$\zeta^{(\alpha\delta)}$
$\mathbf{\Delta}^{(\alpha\delta)}$	0	$\mathbf{\Delta}_m^{(\alpha\delta)}$	$\mathbf{r}\times\mathbf{\Delta}_m^{(\alpha\delta)}$	$\Delta_\epsilon^{(\alpha\delta)}$	$\Delta_s^{(\alpha\delta)}$

$$\mathbf{\Delta}_m^{(\alpha\delta)}=(2H\nu\mathbf{n}+\mathbf{\nabla}_s\nu)^{(\alpha\delta)},\qquad R^{(\alpha\delta)}=r^{(\alpha\delta)}/\theta^{(\alpha\delta)},\qquad \zeta^{(\alpha\delta)}\geq 0$$
$$\Delta_\epsilon^{(\alpha\delta)}=(2H\nu\mathbf{n}\cdot\mathbf{S}+\mathbf{\nabla}_s\nu\mathbf{S}+\nu\mathbf{\nabla}_s\cdot\mathbf{S})^{(\alpha\delta)},\qquad \Delta_s^{(\alpha\delta)}\geq 0$$

$$\frac{\partial}{\partial t}(\rho^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)})+\mathbf{\nabla}^o\cdot(\rho^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)}\mathbf{v}^{(\alpha\delta)})+\mathbf{\nabla}^o\cdot\mathbf{J}^{(\alpha\delta)}$$
$$-\rho^{(\alpha\delta)}\mathbf{\Phi}^{(\alpha\delta)}=\rho^{(\alpha\delta)}\mathbf{B}^{(\alpha\delta)}$$

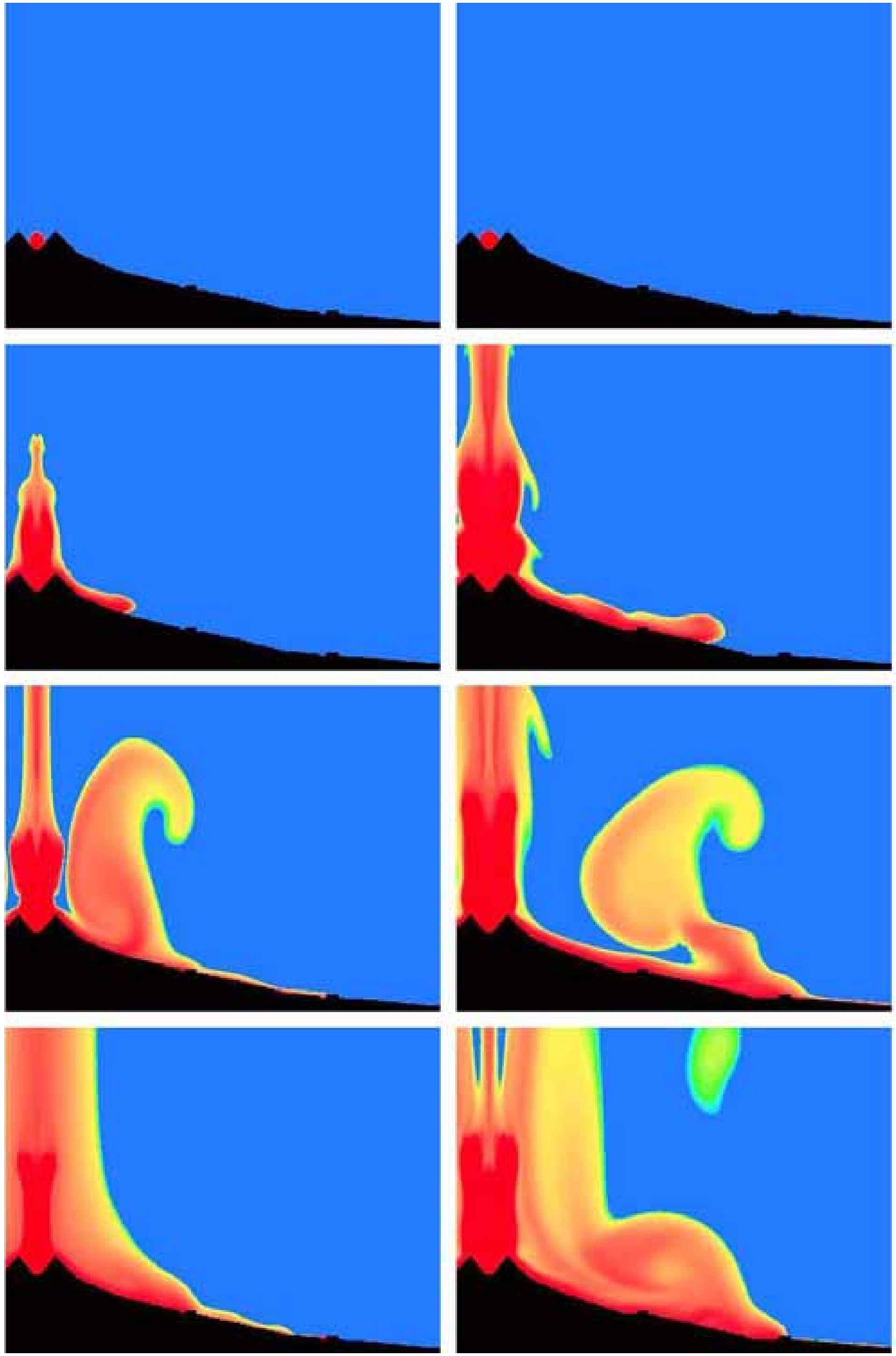
$$(m^{(\alpha\delta)}\mathbf{\Psi}^{(\alpha\delta)}+\mathbf{J}^{(\alpha\delta)}\mathbf{n}^{(\alpha\delta)})+(m^{(\beta\eta)}\mathbf{\Psi}^{(\beta\eta)}+\mathbf{J}^{(\beta\eta)}\mathbf{n}^{(\beta\eta)})=\mathbf{\Delta}^{(\alpha\delta)}$$

$$m^{(\alpha\delta)}=\rho^{(\alpha\delta)}(\mathbf{v}^{(\alpha\delta)}-\mathbf{S}^{(\Lambda\delta)})\cdot\mathbf{n}^{(\alpha\delta)}$$



Southern topography of Vesuvius

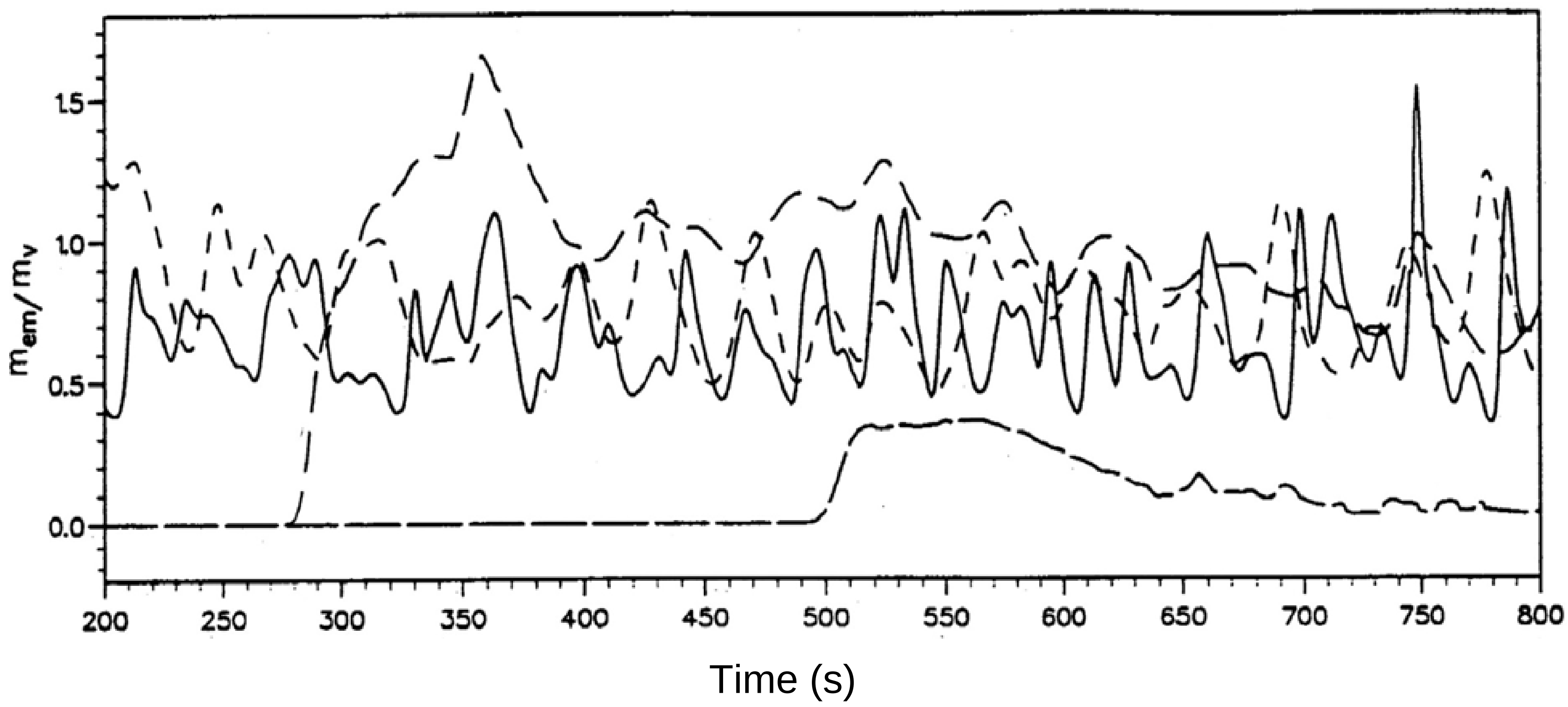
Plinian eruption
20, 120, 300 s



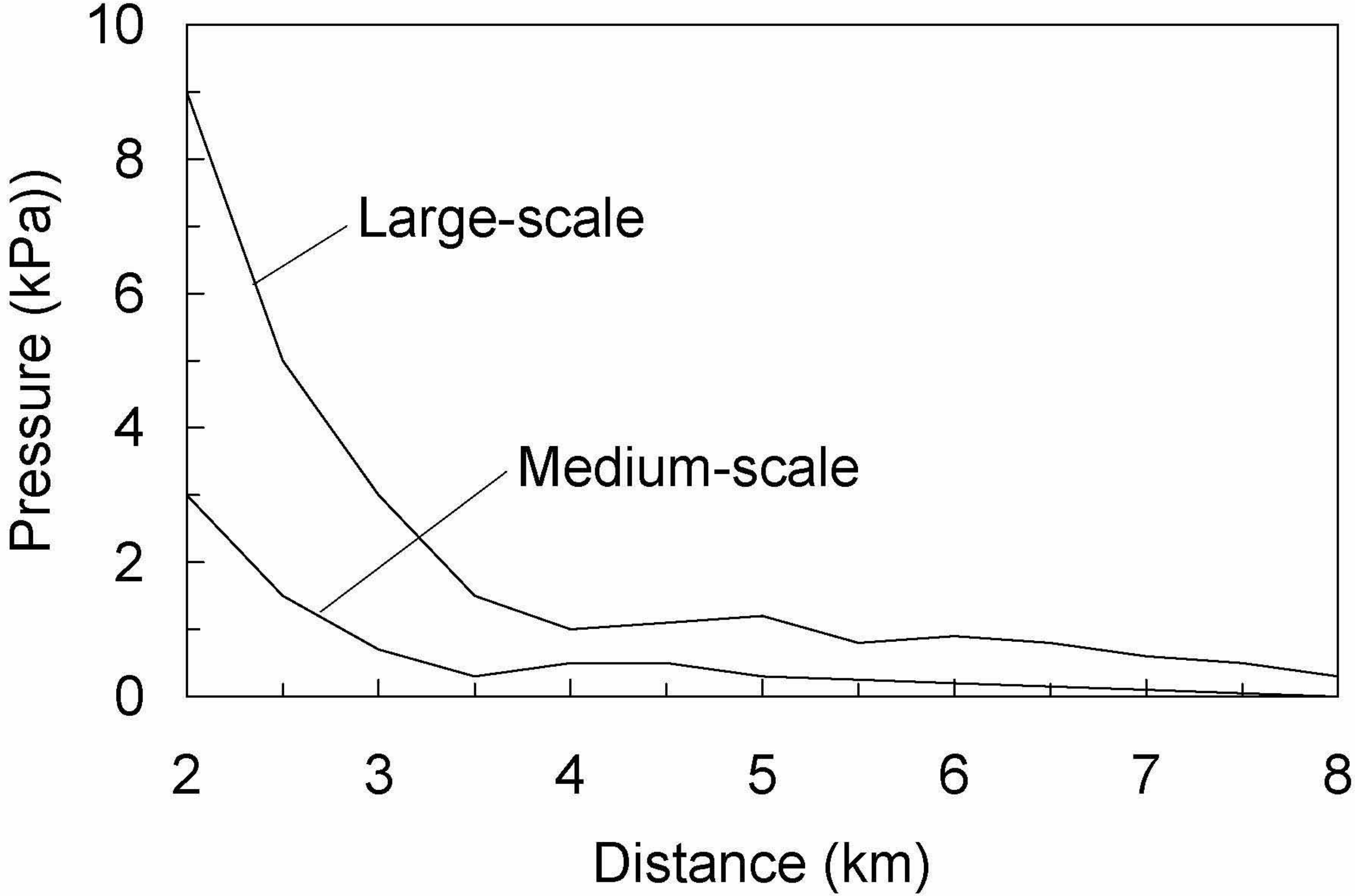
30 m high obstacles
at 3 and 5 km

Sublinian eruption (left)
0, 30, 300, 900 s
Flow stopped at 5 km

Plinian eruption (right)
0, 180, 300, 400 s
Flow stopped at 5 km



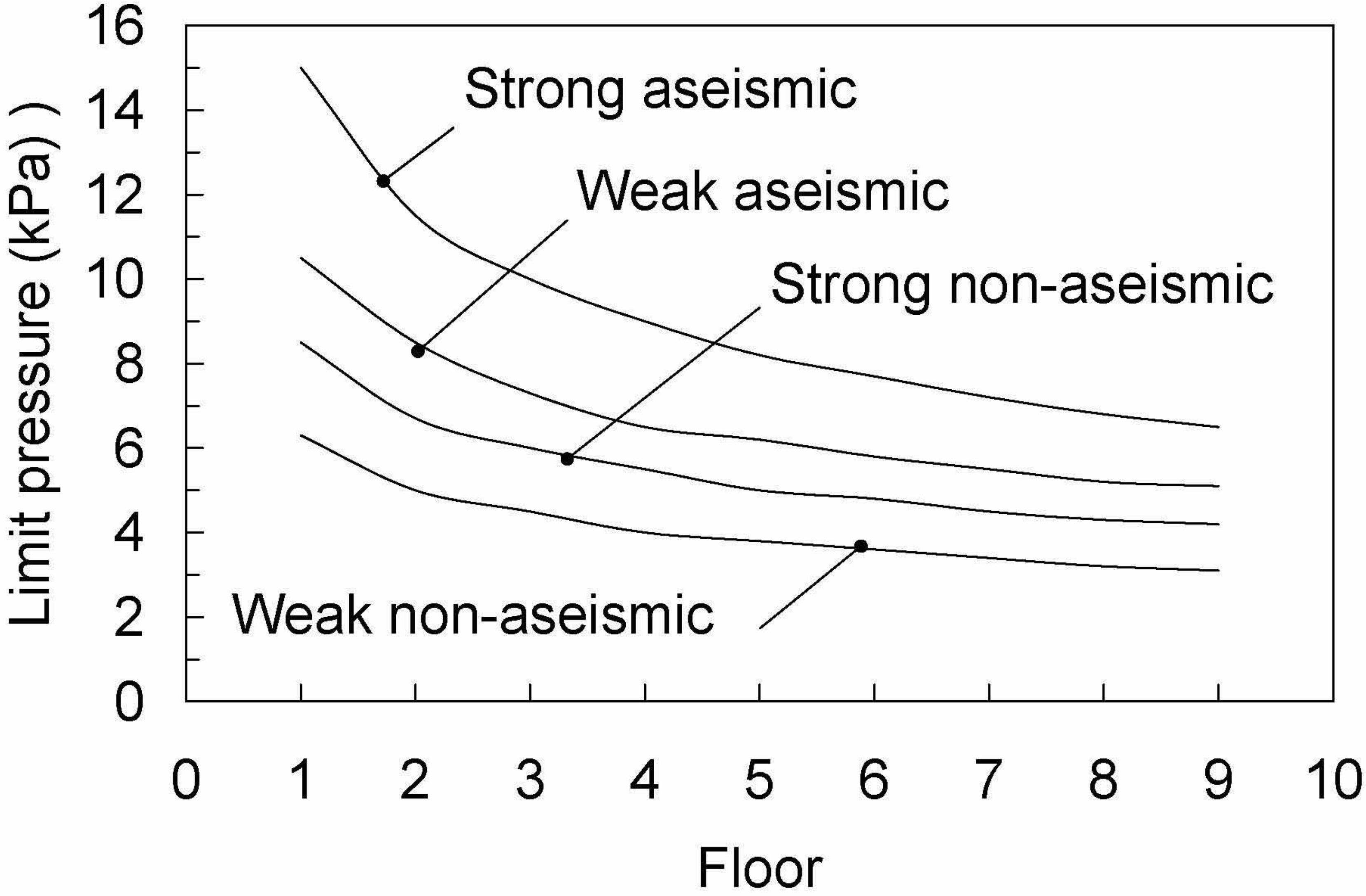
Plinian eruption pyroclastic mass flow loadings: R=3 (solid line), 6 (short dash), 10 (medium dash), 15 km (long dash) from the vent



Dynamic pressure from pyroclastic flow
10 m from the ground

Vulnerability of structures

- Horizontal pressure limits of structures
  - 4-8 kPa (weak non aseismic r.c. blds)
  - 7-9 kPa (yellow tuff masonry walls)
  - 6-14 kPa (strong aseismic r.c. buildings)
  - 20-26 kPa (volcanic masonry buildings)
- Roof loading from tephra
  - 4500 kg/m^2 (< 5 km)
  - 3000 kg/m^2 (5-8 km)
- Pyroclastic flow/surge loading
  - < 2 kPa (> 5 km), 200-500^{o}C
    (human survival <5 min)



Structural mechanics calculations

(Petrazzuoli & Zuccaro 2004)

Vulnerability of structures

- Seismic Zoning (Panza & co-workers)
  - Input: source and medium characteristics
    actual or parametrized
  - Output: ground displacement, velocity,
    acceleration, frequency content
  - Vesuvius area:
    $displacement_{max}$ = 20 cm; period = 30 s
    $velocity_{max}$ = 60 cm/s; period = 25 s
    $acceleration_{max}$ = 0.5 g

Vulnerability of structures

- Structures incorporating Response Control Systems to dissipate seismic energy (Mazzolani & co-workers)

  - ➢ Seismic isolation
  - ➢ Energy dissipation
    (hysteretic and/or viscous dampers elements)
  - ➢ Mass effect systems
    (systems resonating out of phase with source)

Future habitat for Vesuvians

- The Grand Challenge
  - exclusion zone (< 5 km radius)
  - limited protection (5-8 km radius)
  - sustainable habitat (> 8 km radius)
  - engineers need to understand:
    - patterns of supply and use of materials, energy, information, services, products
    - protection measures against earthquakes, tephra fall, fyroclastic flows, ballistic blocks

- Urban center design imperatives
  - Sustainability
    - basic human needs (food, water, space)
    - socio-political rights
    - health care
    - education
    - equitable distribution of resources
    - jobs
    - housing
    - sense of belonging
    - limited geographical & resources footprints
    - autoregulation of territory
    - manageability

- System of systems approach
  - balance localized and centralized activities
  - spread transportation, utilities, recreation, business, residential neighborhoods across interconnected clusters
  - decide levels of interaction between
    - <u>biological component</u> (human activities, vegetation, microorganisms)
    - <u>social component</u> (ideas, collective, activities, organizations of inhabitants)
    - <u>machine component</u> (life support artifacts)

- Engineering challenges
  1. What are the sustainability design paradigms?
  2. How will safety requirements limit options in other sectors?
  3. Does the defense from the volcano require new paradigms for urban infrastructure?
  4. Is homeland defensible against all conceivable scenarios?
  5. What methods of energy supplies and waste disposal and recycling are required?

- Engineering challenges (continued)

6. What kind of habitat (centralized vs. clustered?
7. How will the habitats interact with Naples and surroundings?
8. What cultural patrimonies can be protected and how to protect them?
9. What can remain within the exclusion zone?
10. How to effectively cooperate with politicians, other professionals, and people?

VESUVIUS 2000 (Dobran et al. 1995, 2006)

- Objectives
  - Determine scenarios and likelihoods
  - Assess vulnerabilities
  - Develop educational methodologies
  - Produce sustainable habitat(s)
- Methodology
  - Physical environment
  - Population
  - Territory

Vesuvius evacuation plan: Mass deportation

Conclusions

- Sustainable habitat(s) should be built for Vesuvians (> 8 km from the volcano)
- Employ habitat design tools:
  Global Volcanic Simulator, Seismic Zoning, Urban System Simulations, Response Control Systems, etc.
- Involve politicians, people, professionals
- Start working now