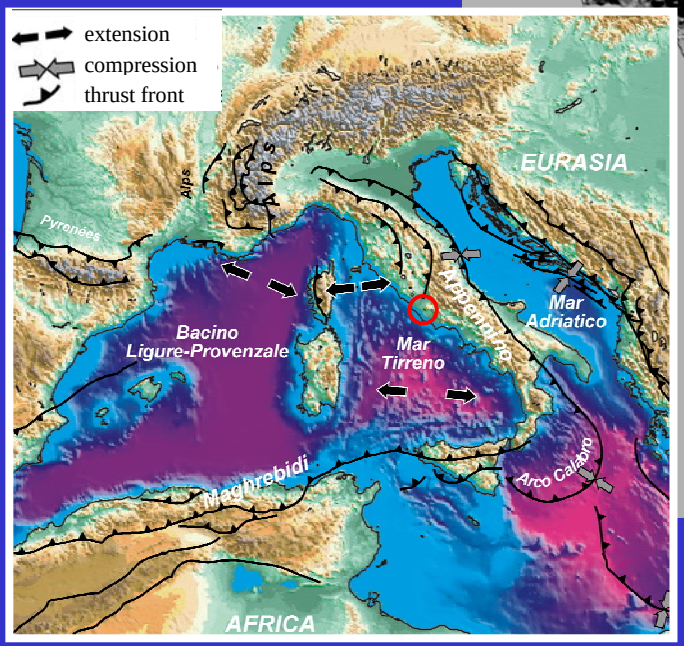
The roots of Urban Geology: the City of Rome

Renato Funiciello *– Dip. Scienze Geologiche, Univ. "Roma TRE", Italy*

Outlines

- ✓ Geological setting of Rome
- ✓ Natural and geological factors that made the fortune of Rome
- ✓ How the same geologic processes threatened Roman life and represent a source of risk for Roman inhabitants and properties
- ✓ What are the geologic risks in the city of Rome:
  - Volcanic risk
  - Seismic risk
  - Subsidence
  - Floods
- ✓ Conclusions

GEOLOGICAL SETTING OF ROME



Sabatini volcanic complex

Apennine chain

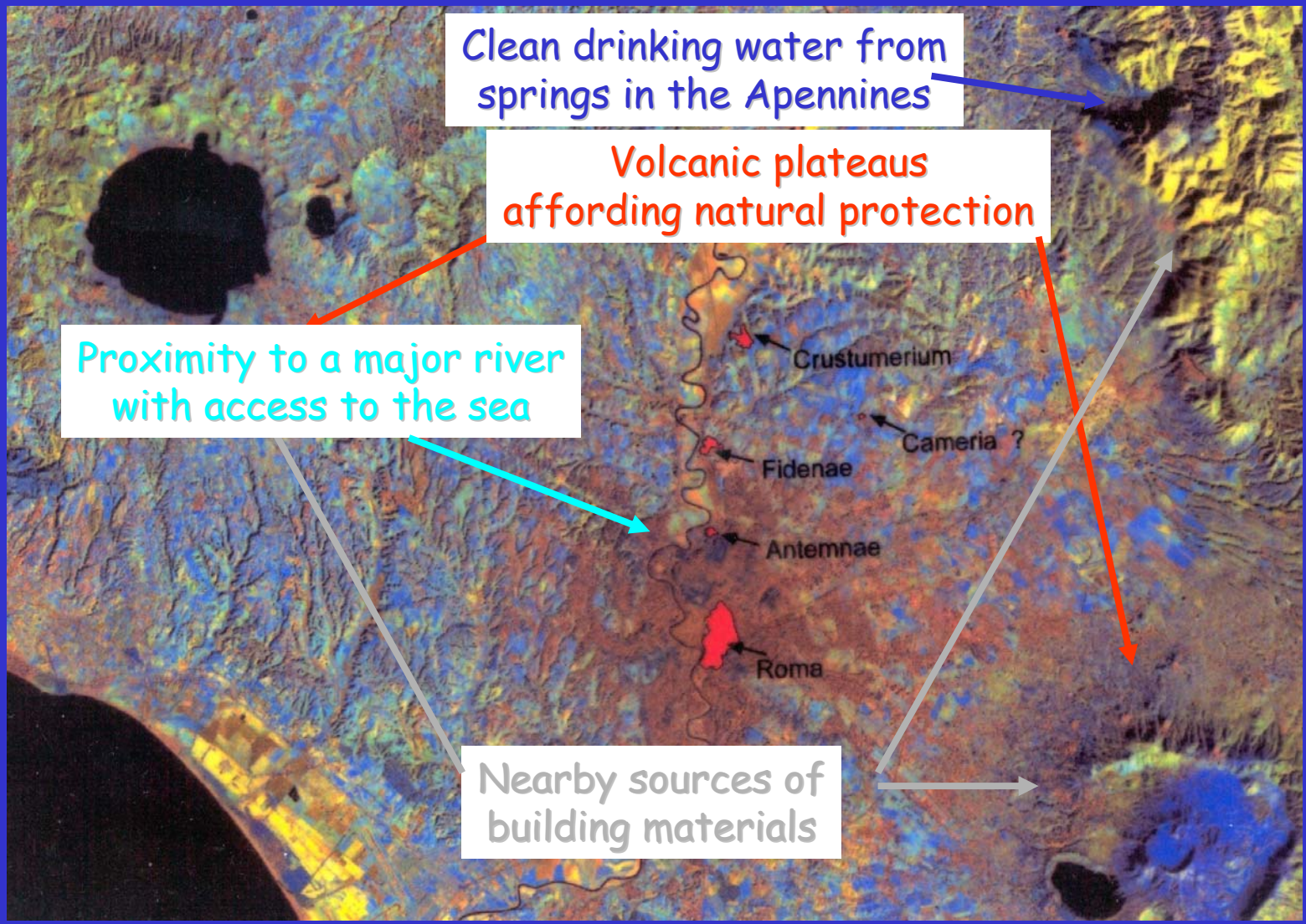
Tiber river

Roma

Alban Hills volcanic Complex

NATURAL AND GEOLOGICAL FACTORS THAT MADE THE FORTUNE OF ROME

Which is the "*geologic*" origin of the fortune of Rome?



Geological processes have also threatened Roman life and property with :

- Floods
- Earthquakes
- Landslides
- Volcanic eruptions (in the Bronze Age!)

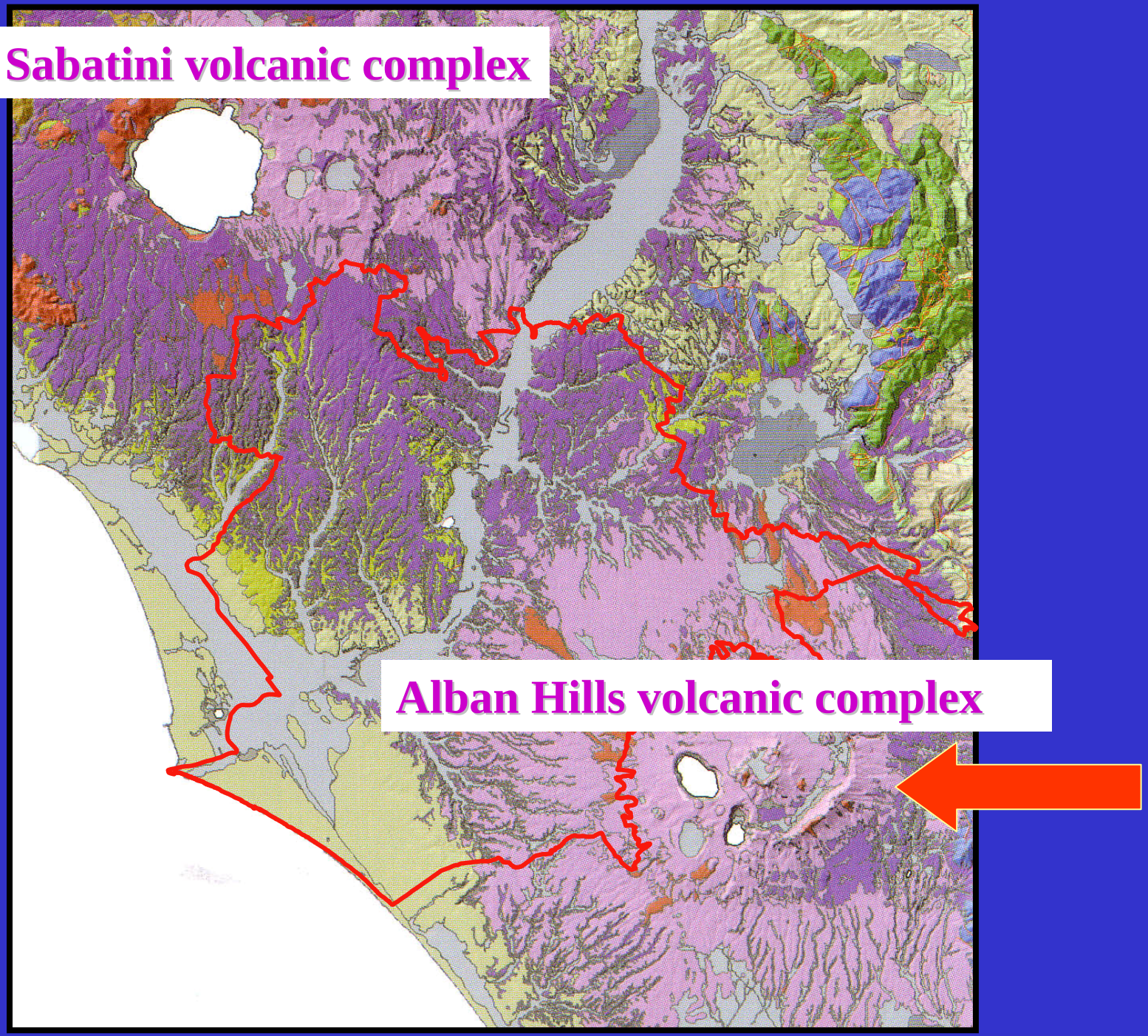
Ancient Romans were aware of the natural hazard that threatened the urban life

FIRST URBAN PLANNING IN THE HISTORY

Natural risks in the city of Rome

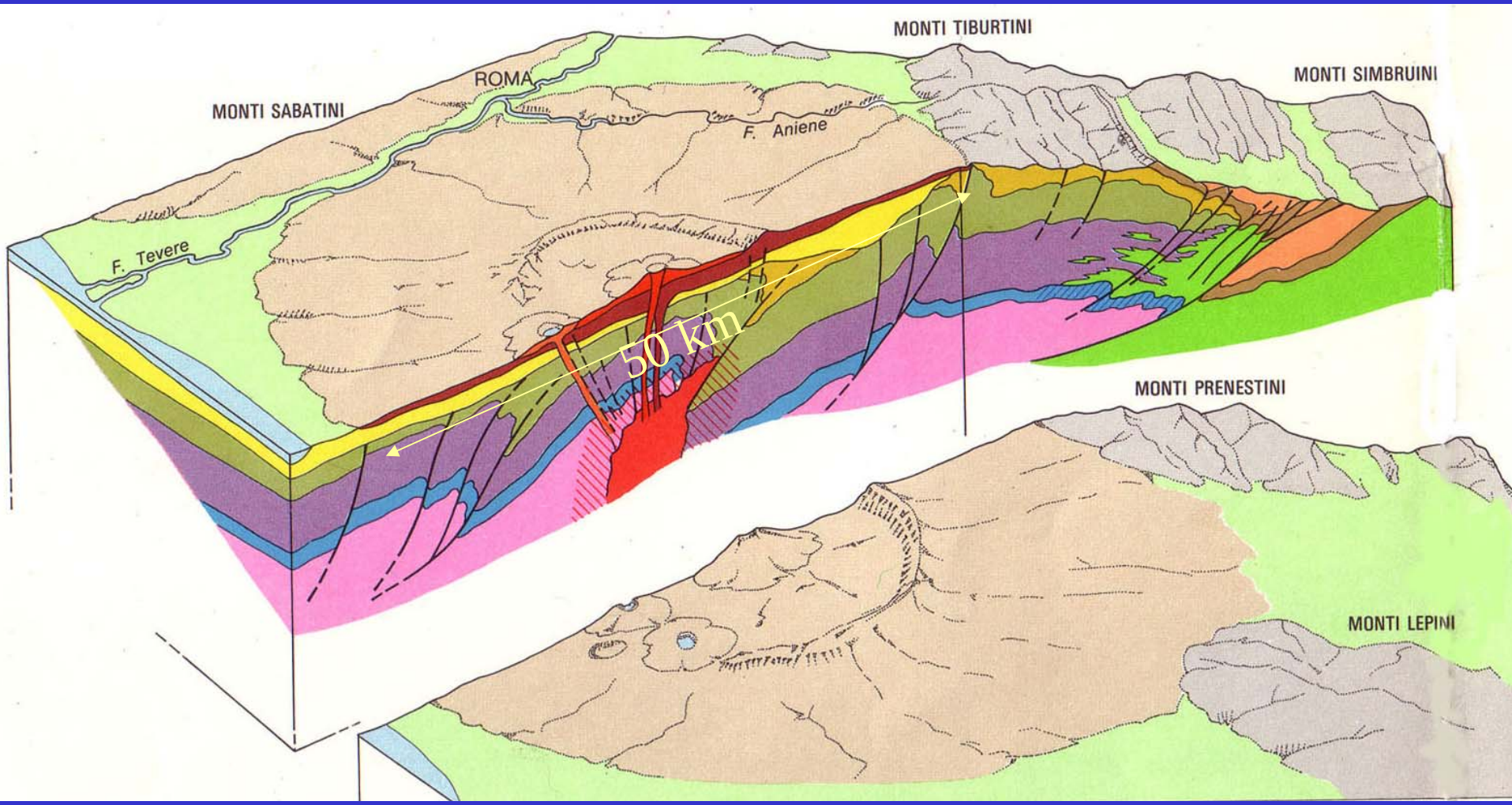
Source of Risk	Potentially interested areas	VAL evaluation for Rome	Characteristic time for the event	Probability that the event takes place in the next 100 yrs	Risk
Volcanic activity	Whole the roman area	VAL	Extremely high	Close to 0	Close to 0
Seismic activity	Area characterized by Holocene alluvium deposits	VAL/5	30 years (VI MCS)	High	Medium-high
Subsidence	Area characterized by Holocene alluvium deposits	VAL/5	Continuous phenomenon	Continuous phenomenon	Medium-high
Flood	Aniene basin	VAL/500	20 years	High	Medium-low
Landslides	Along the escarpments delimiting morphologic highs	VAL/1000	1 year	Very high	Medium

The volcanic risk in the city of Rome

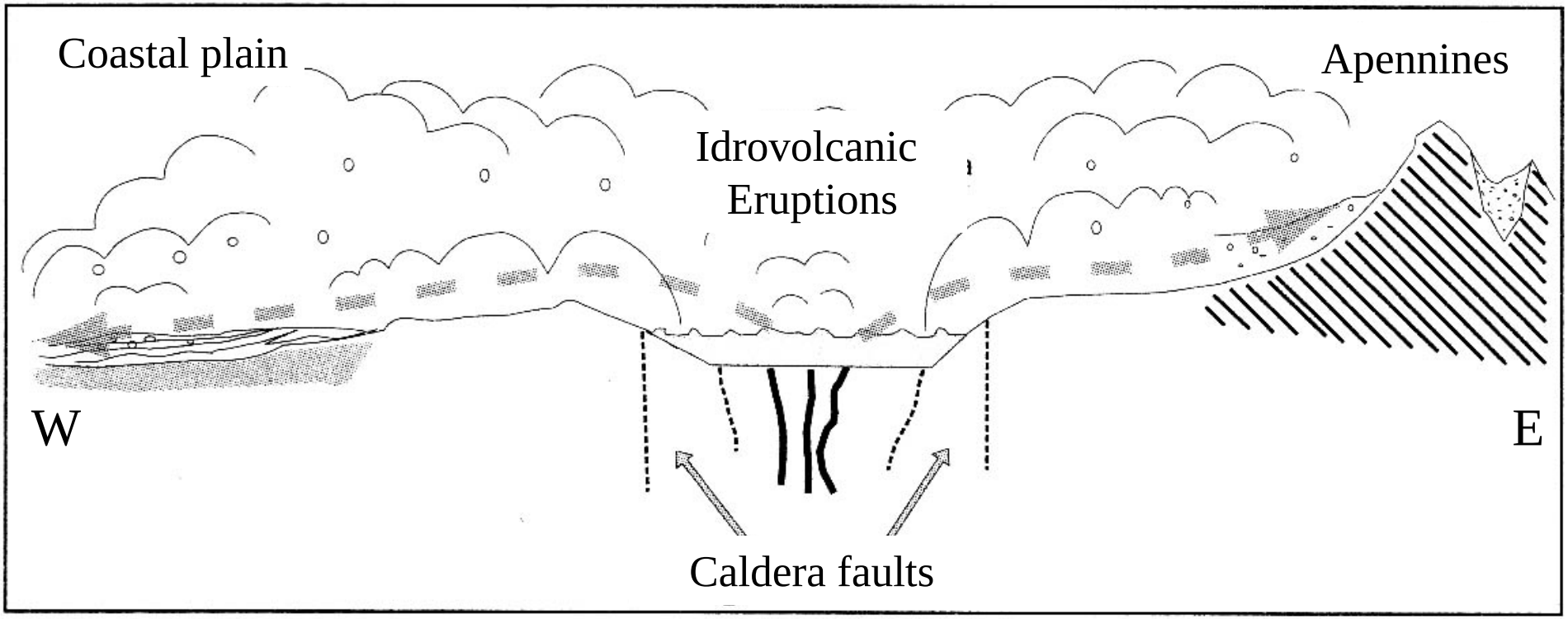

Sabatini volcanic complex
Alban Hills volcanic complex


Alban Hills

Schematic geologic cross-section of Alban Hills

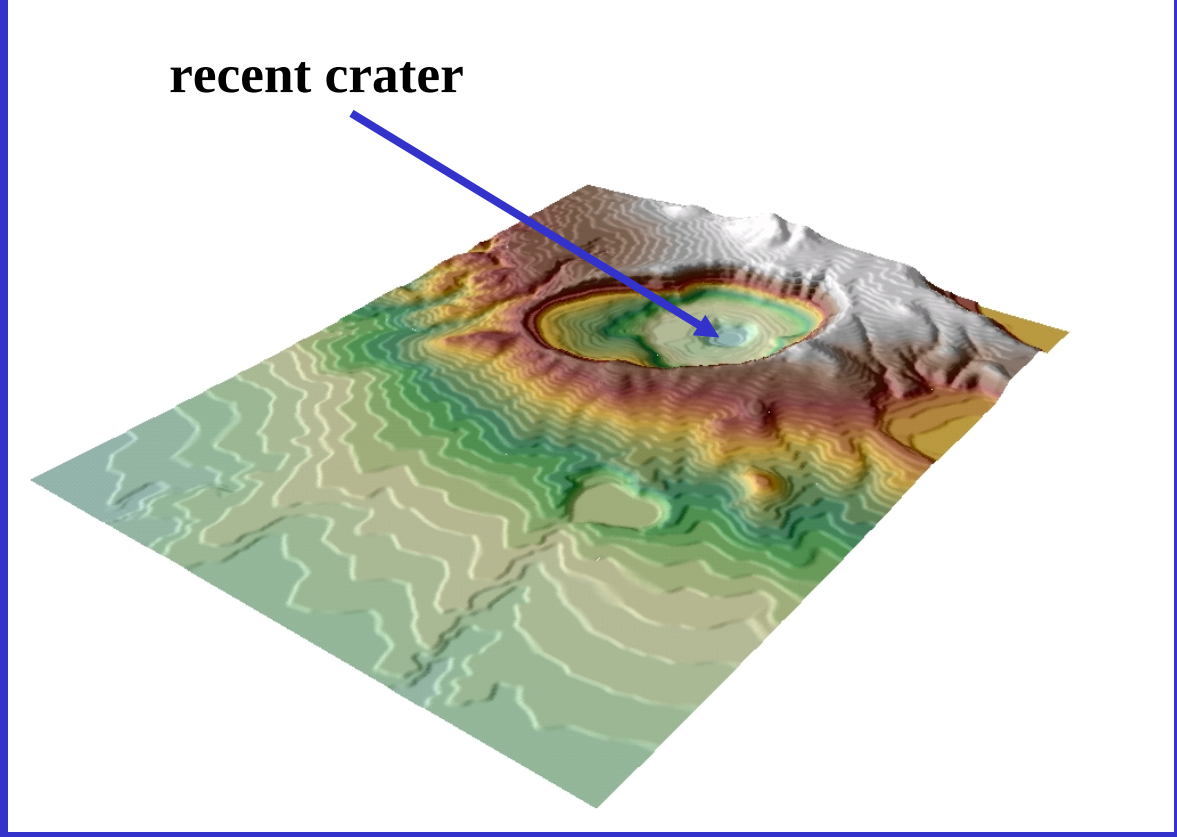


First volcanic eruptions were very explosive
due to the interaction between magma and water



Areal extension of volcanic flows was very large,

reaching the sea to the west and the flanks of Apennines, over 200 m a.s.l.



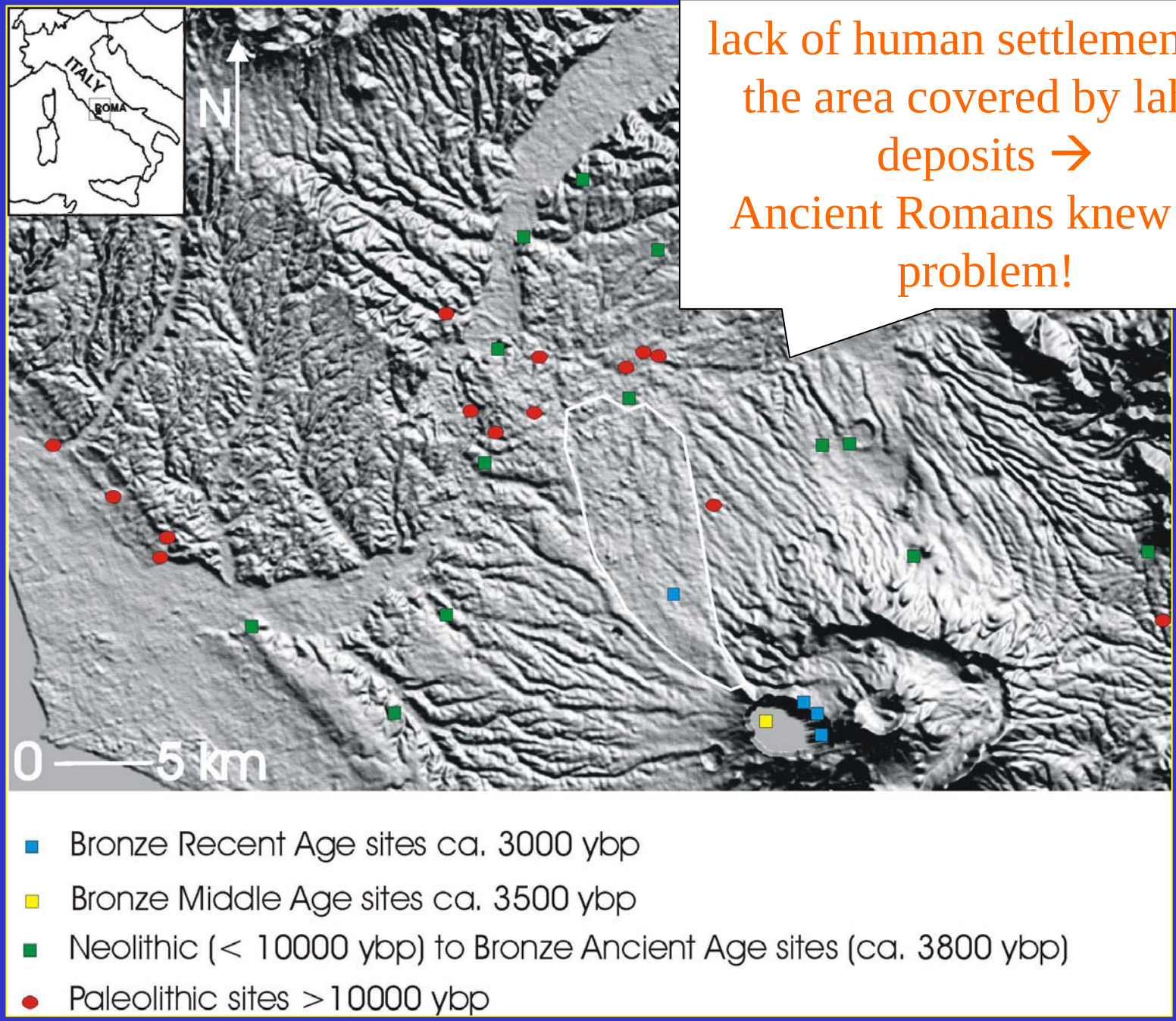
- 30 cm of uplift in the last 40 years

- systematic occurrence of seismic swarms

the Alban Hills volcanic activity is not yet extinct

VOLCANIC RISK EVALUATION

Lahar = type of mudflow composed of pyroclastic material and water that flows down from a volcano


ITALY
ROMA
N
0
5 km
lack of human settlements in the area covered by lahar deposits →
Ancient Romans knew the problem!
Bronze Recent Age sites ca. 3000 ybp
Bronze Middle Age sites ca. 3500 ybp
Neolithic (< 10000 ybp) to Bronze Ancient Age sites (ca. 3800 ybp)
Paleolithic sites >10000 ybp

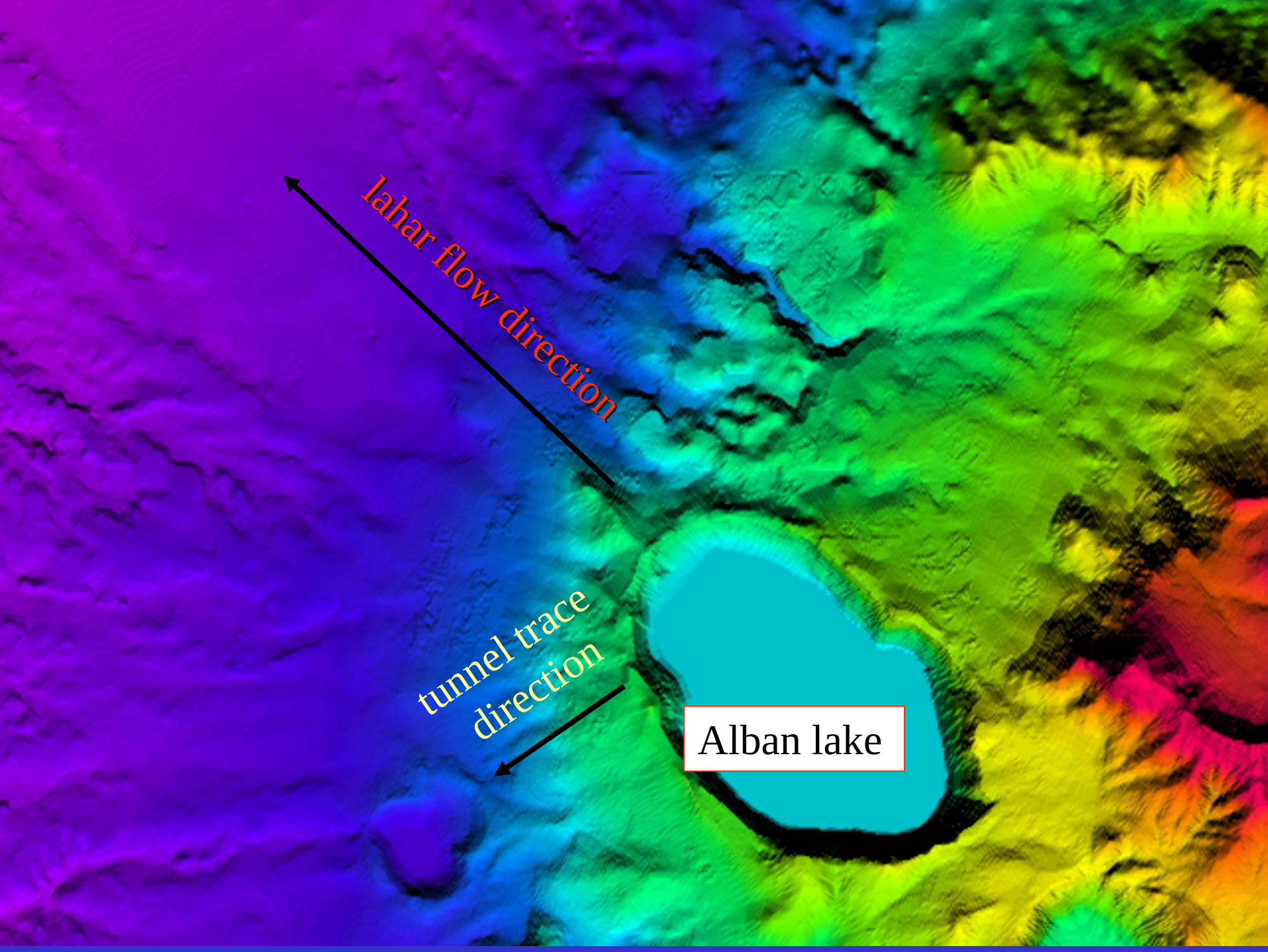

Caldera rim
Alban Lake crater
Ciampino plain

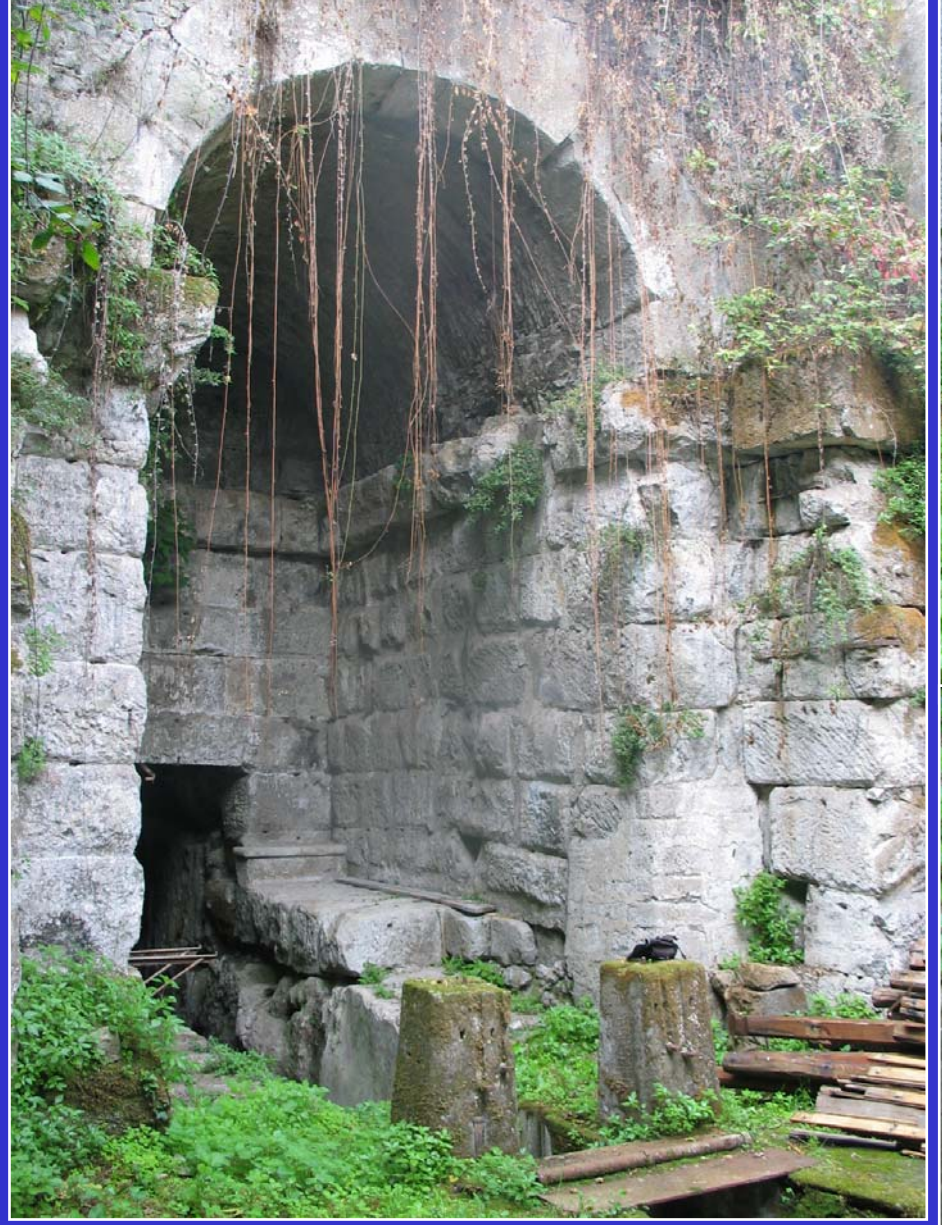

When did the last lahar occurred?

Ancient Roman writers described the catastrophic and sudden uplift of the lake water level and the flood in the Ciampino Plain in 398 b.C.

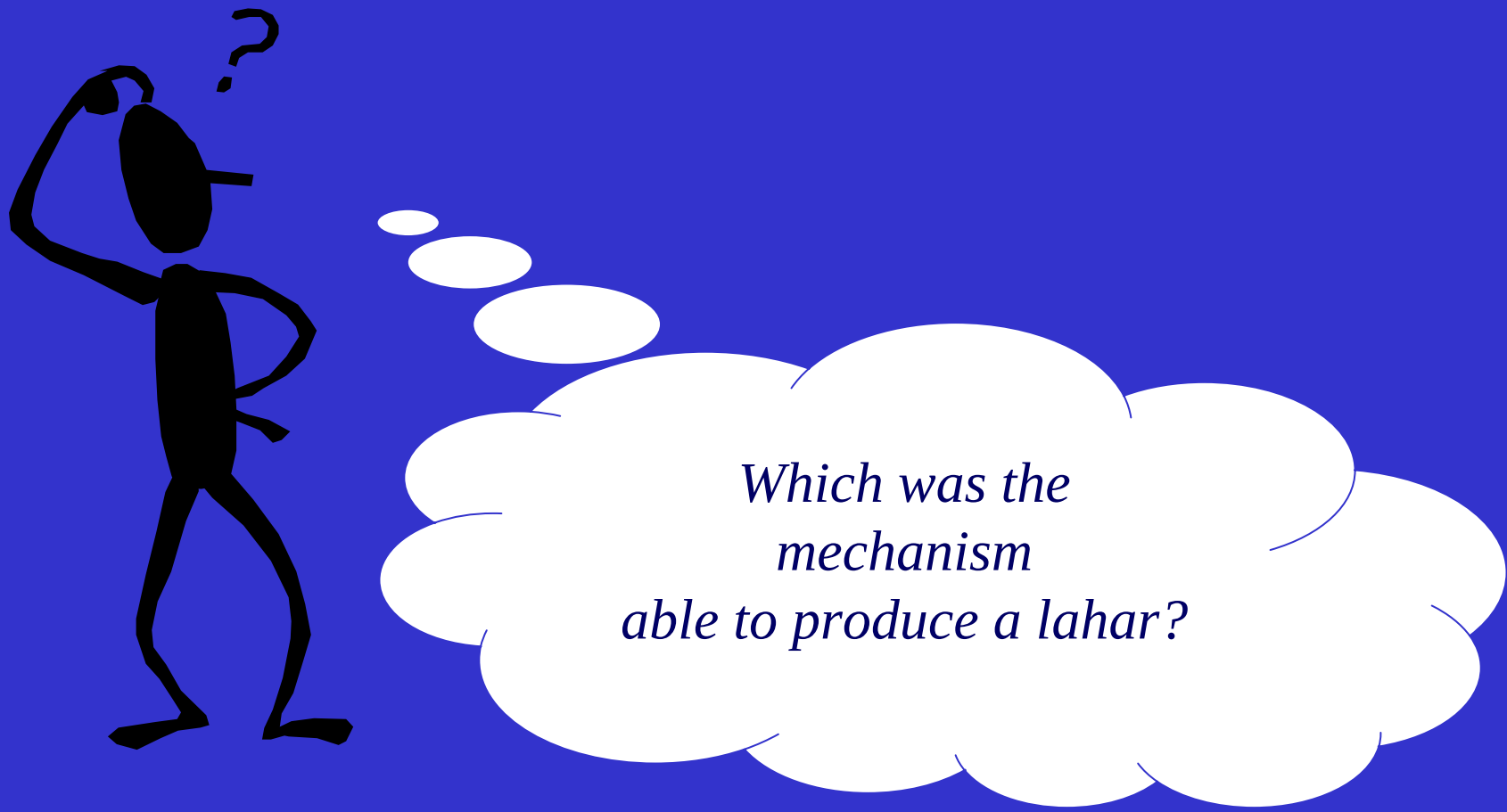
In only four years Roman engineers built a artificial channel that kept the water level constant at 293 m a.s.l.

THIS IS THE FIRST EXAMPLE OF MITIGATION RISK IN A VOLCANIC AREA KNOWN IN THE HISTORY (4^{th} CENTURY b.C.)

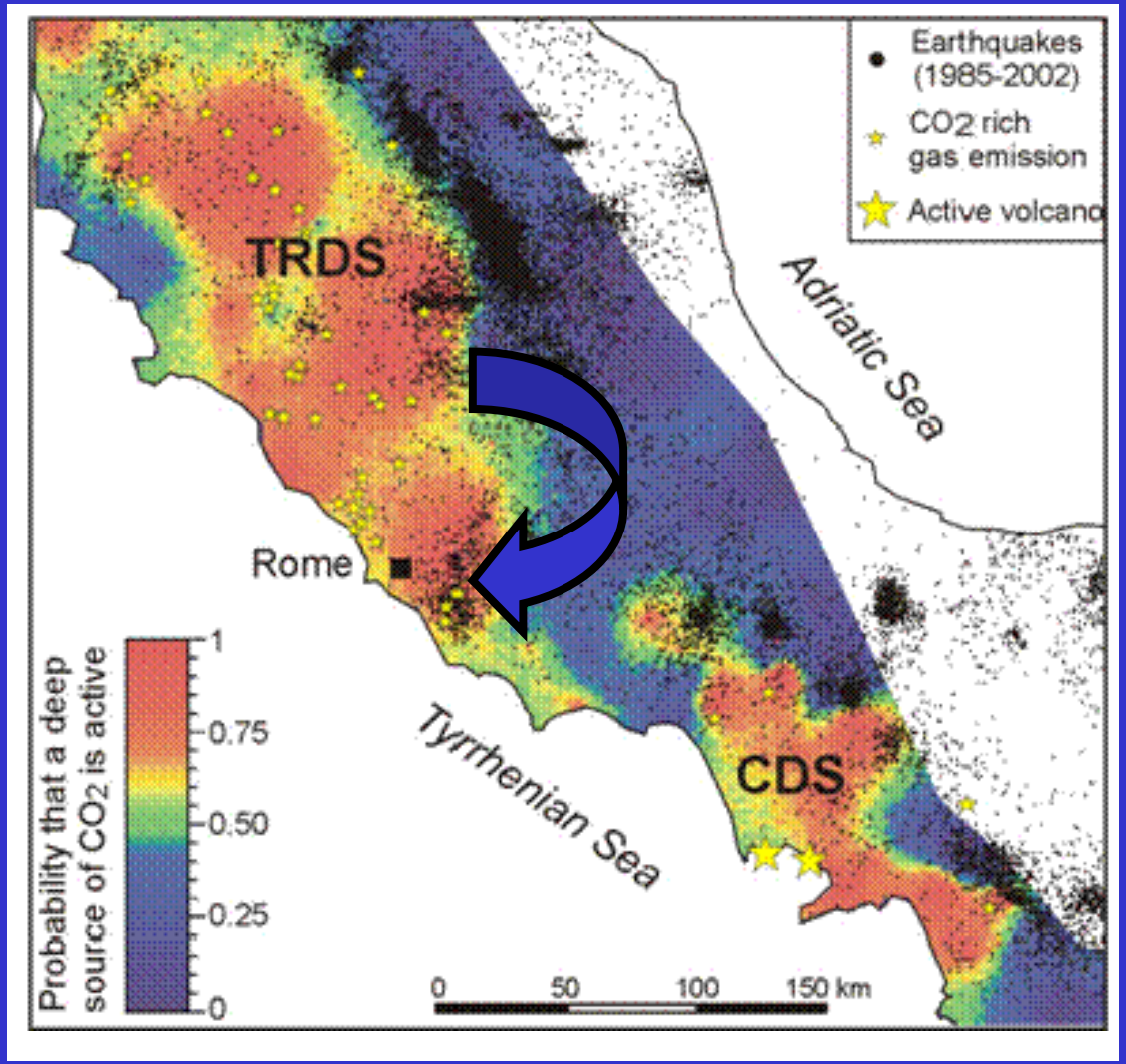

lahar flow direction
tunnel trace direction
Alban lake

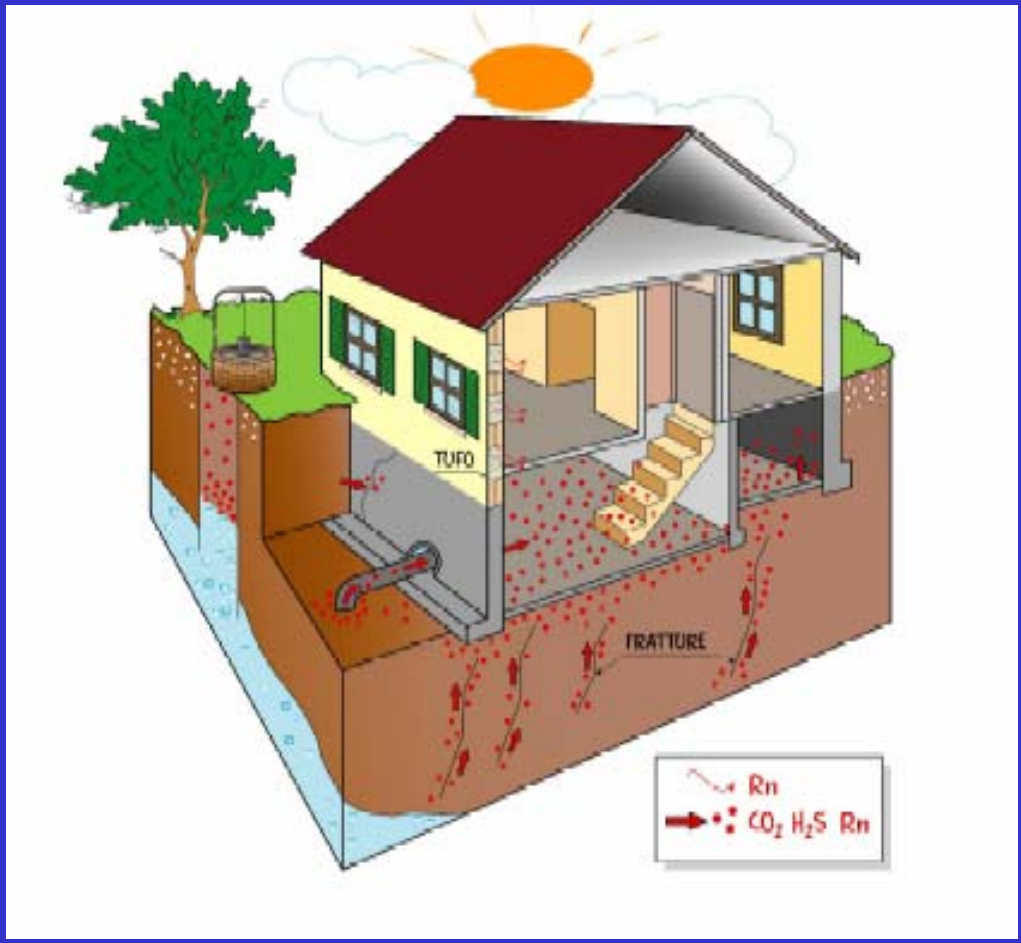


Artificial “roman” tunnel


Which was the
mechanism
able to produce a lahar?

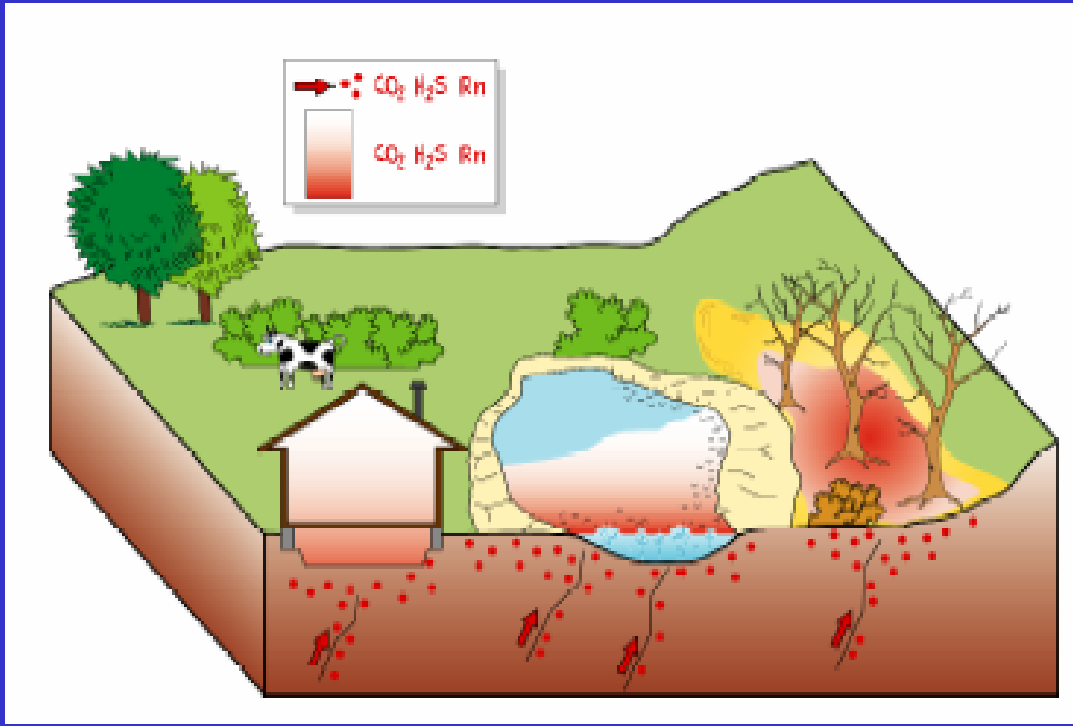
Gas emission related to volcanic activity





Gases (CO_2, H_2S, Rn) may reach the basement of buildings along small fractures in the soil or along pipes

Gases are heavier than air and, when there is no air ventilation, can stagnate in the floor

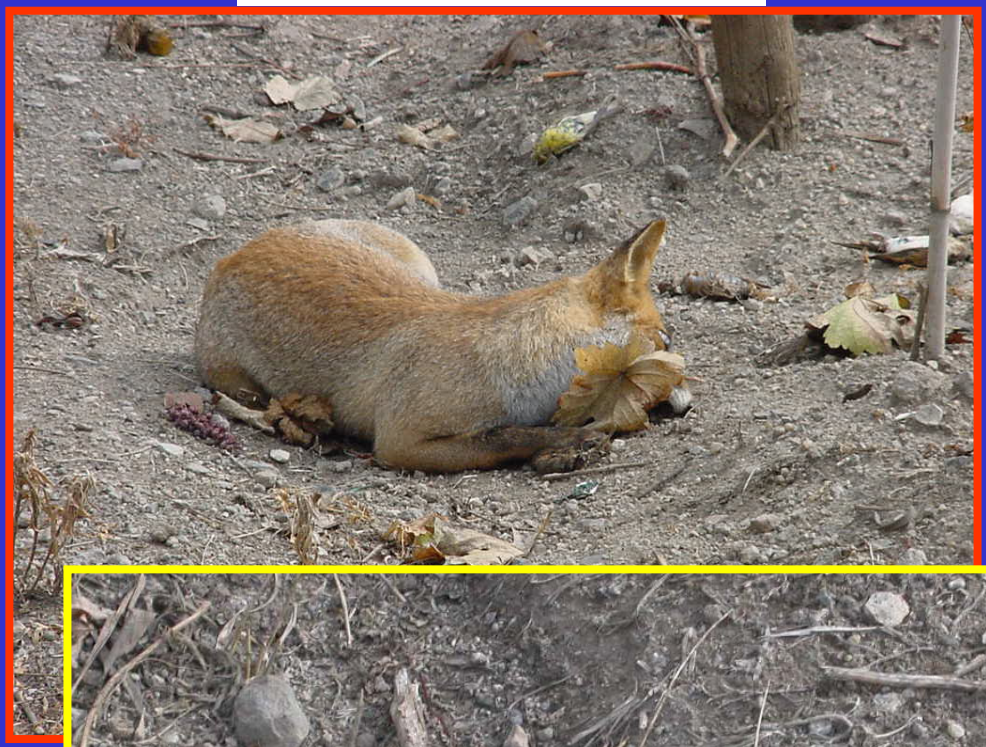


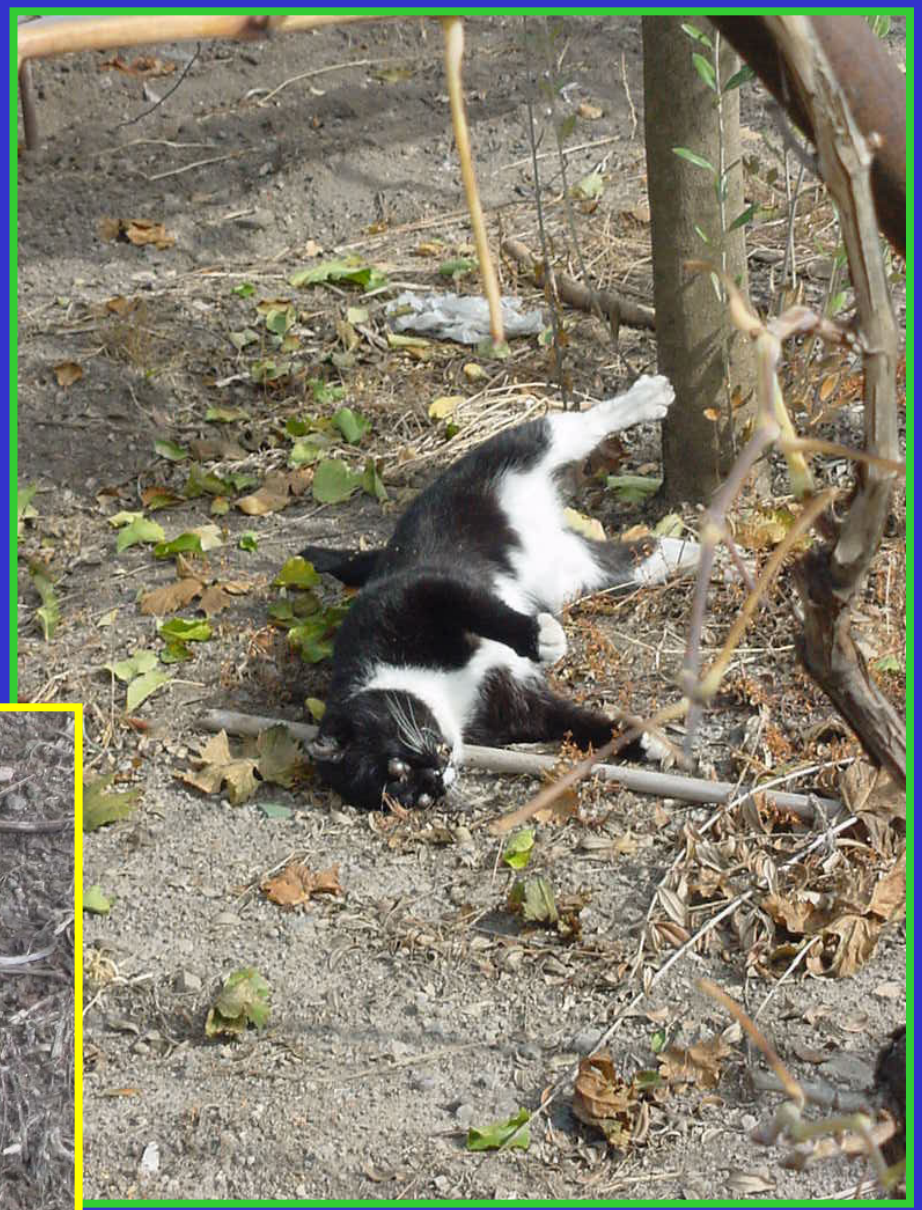
Ascending gases (CO_2, H_2S, Rn) may pool in depressions (stagnant water or mud puddle), burning vegetation or soffocating animals

burnt vegetation

burnt vegetation

animals killed by gas emissions



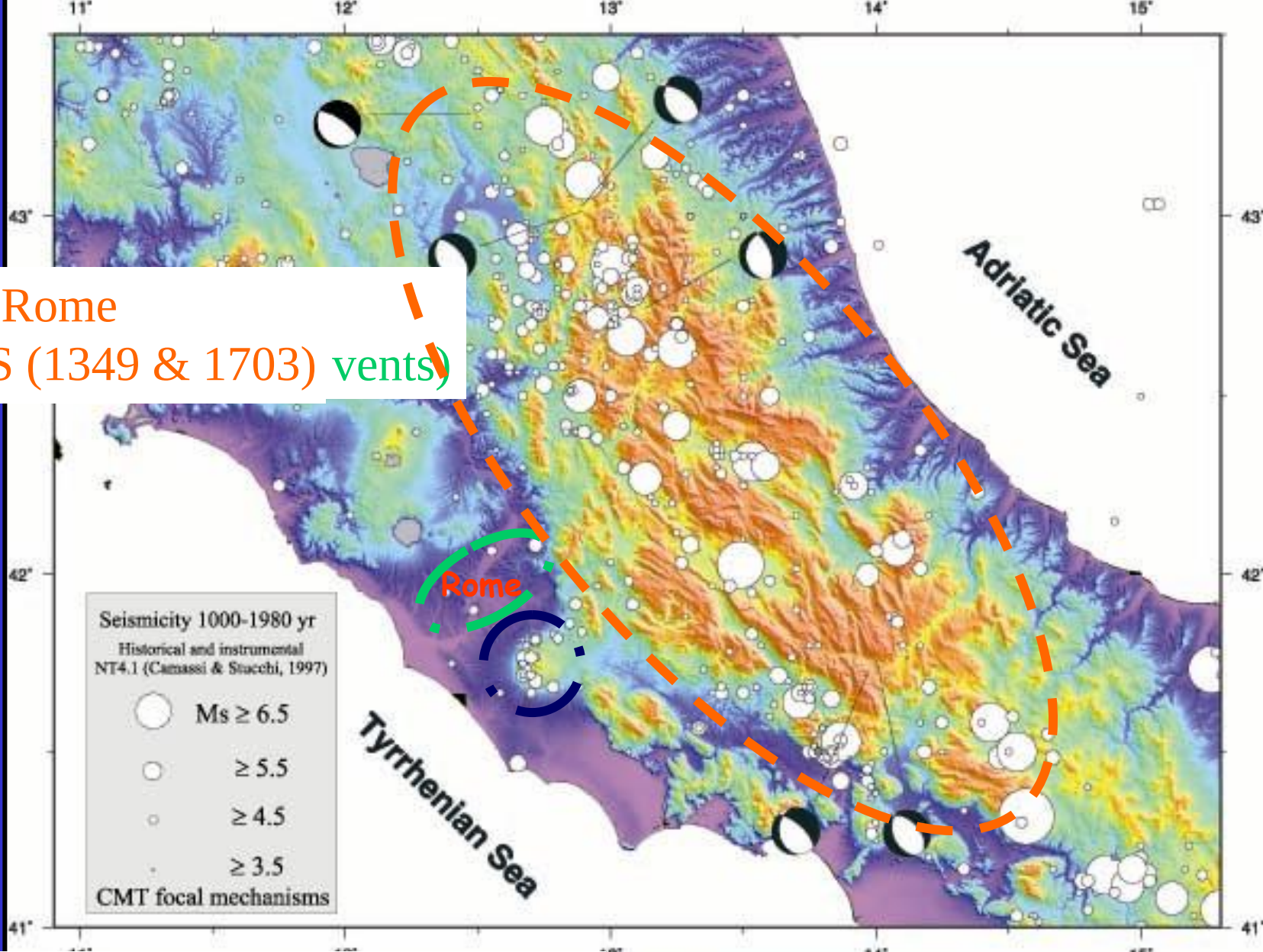


the greatest threat posed by the Alban Hills at this time is the emission of CO_2

Natural risks in the city of Rome

Source of Risk	Potentially interested areas	VAL evaluation for Rome	Characteristic time for the event	Probability that the event takes place in the next 100 yrs	Risk
Volcanic activity	Whole the roman area (gas→ Alban Hills)	VAL	Extremely high (gas→ frequent)	Close to 0 (gas→high)	Close to 0 (gas→ high)
Seismic activity	Area characterized by Holocene alluvium deposits	VAL/5	30 years (VI MCS)	High	Medium-high
Subsidence	Area characterized by Holocene alluvium deposits	VAL/5	Continuous phenomenon	Continuous phenomenon	Medium-high
Flood	Aniene basin	VAL/500	20 years	High	Medium-low

Seismic risk and subsidence in modern Rome



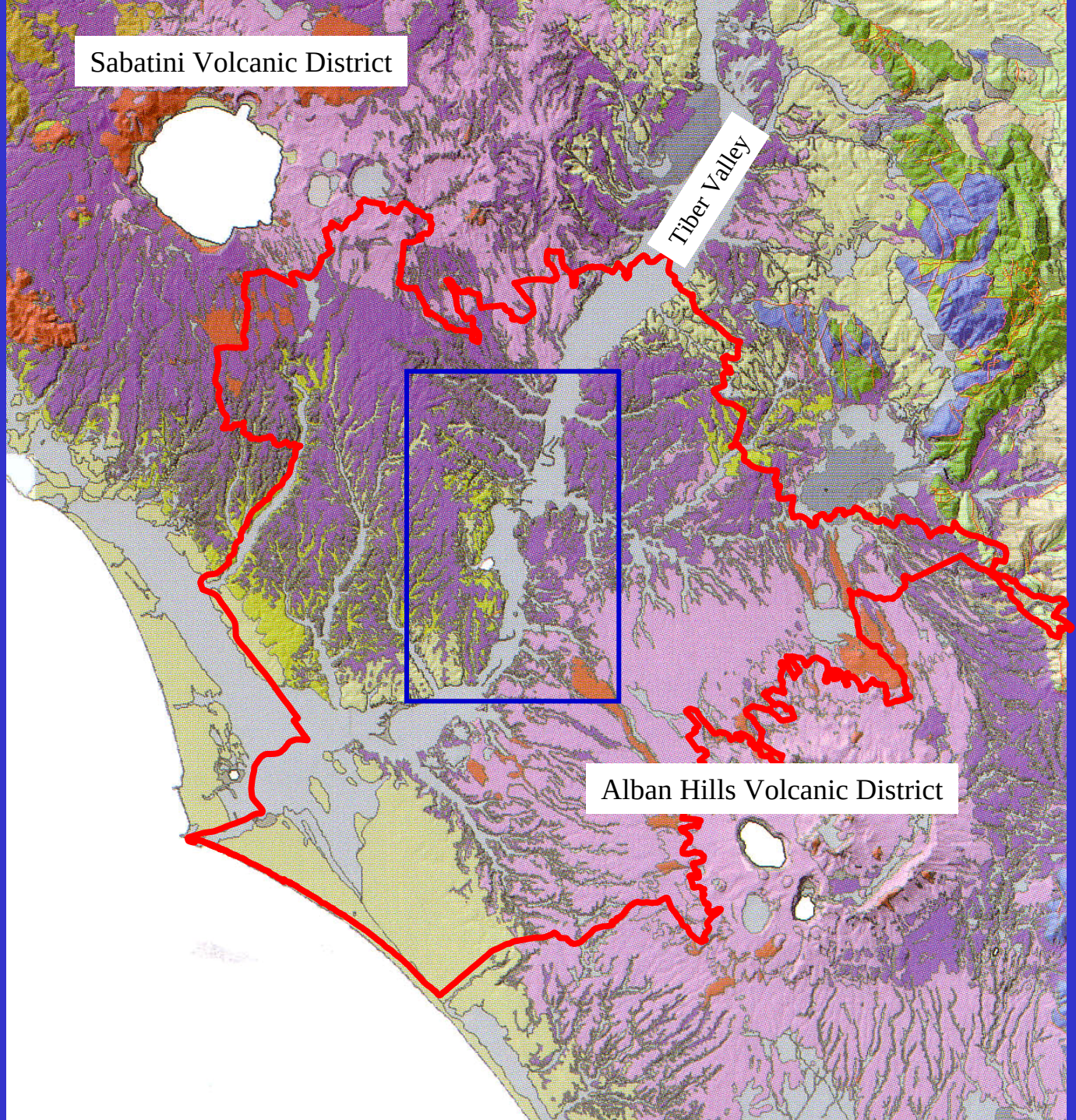
- **Regional Earthquakes** *I= 10-15 km*
- **Local Earthquakes from Alban Hills** *I= 5-10 km*
- **Urban Earthquakes** *I < 10 km*

Even if Rome is not a seismic area

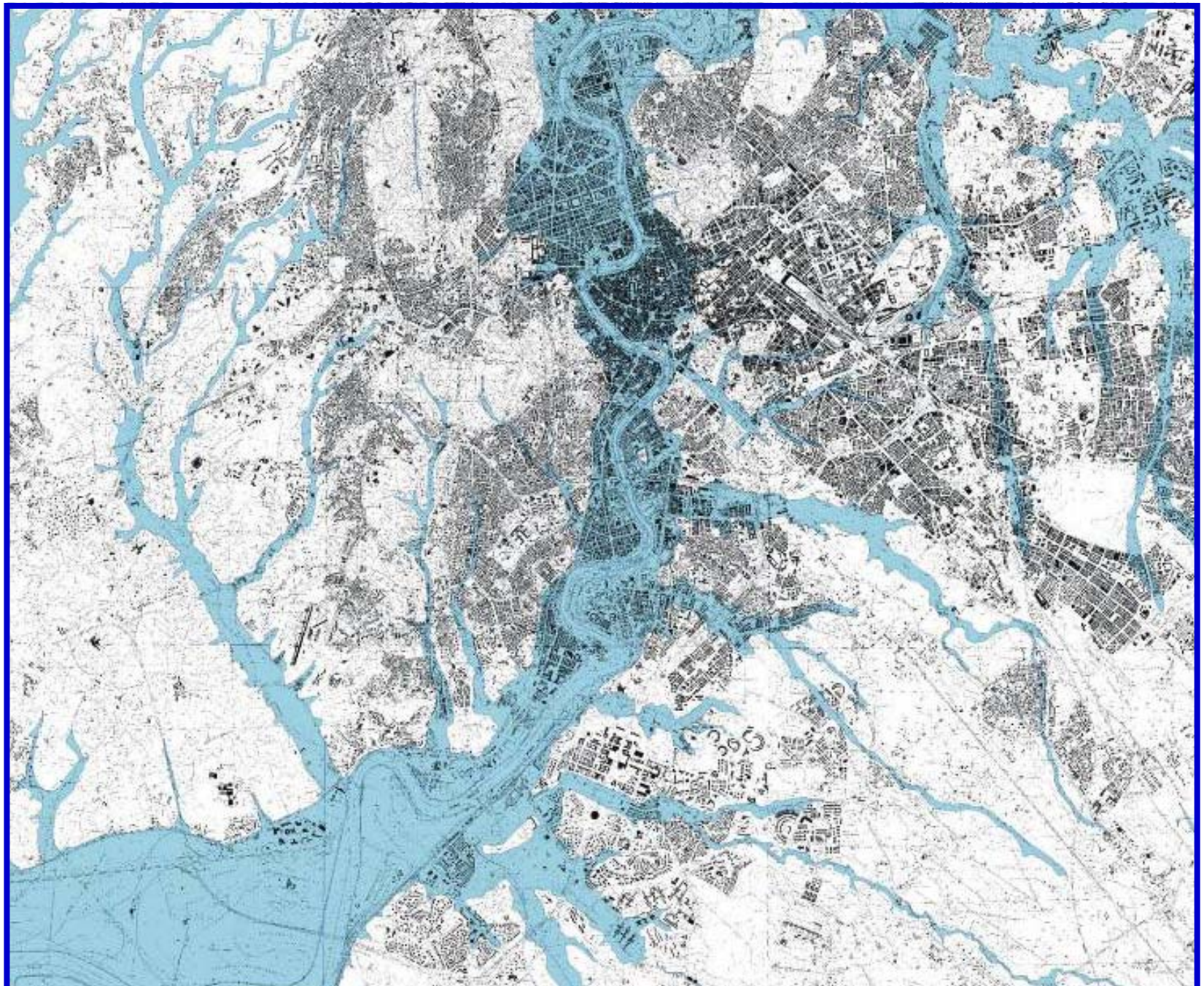
earthquakes

are strongly felt!!!

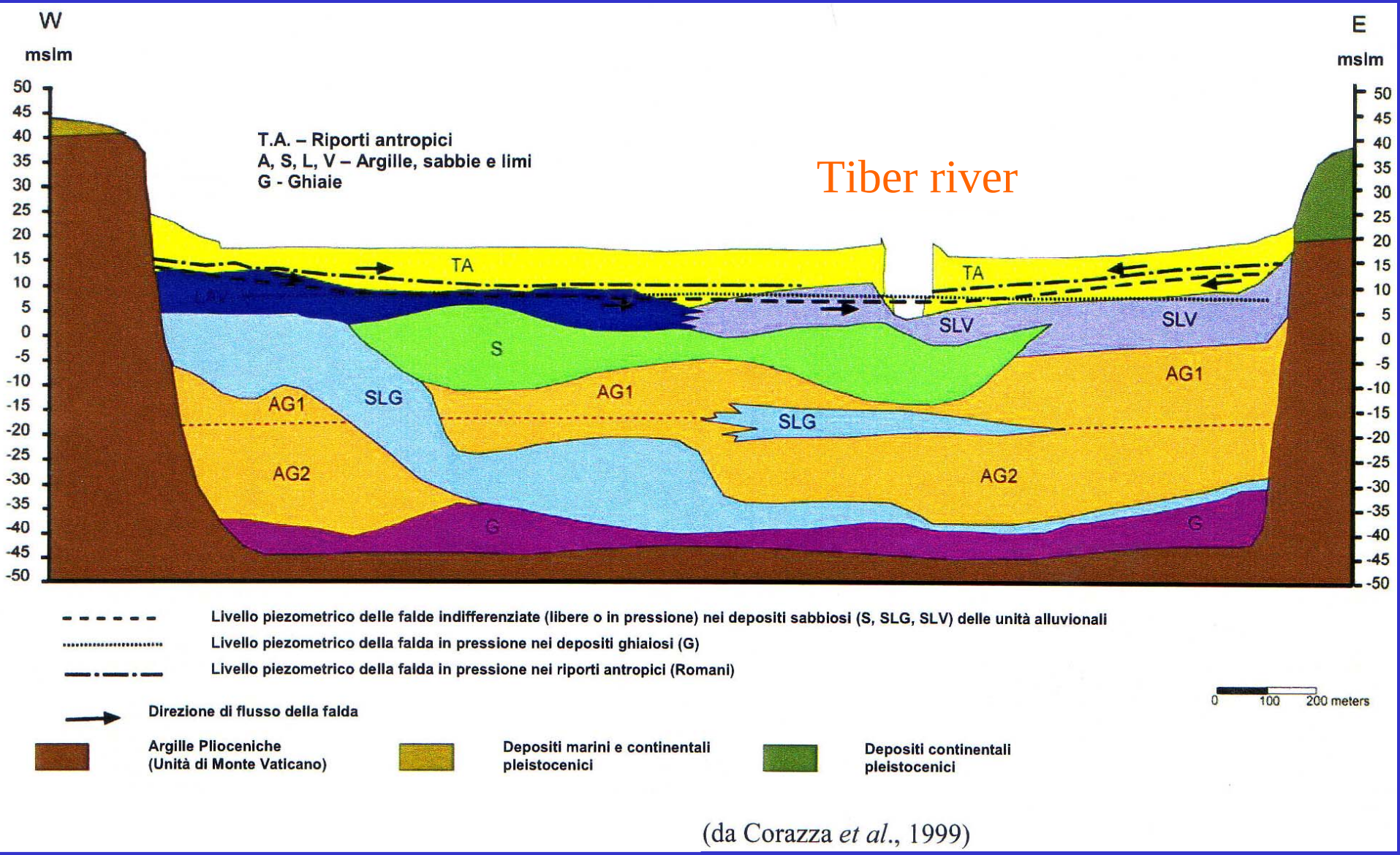
major seismic effects occurr in alluvial deposits



MOST OF THE BUILDINGS/MONUMENTS ARE BUILT ON ALLUVIAL DEPOSITS



Heterogeneity of alluvial deposits



(da Corazza *et al.*, 1999)

– Elastic and anelastic parameters used for the near-surface propagation modelling.

Geological unit	Density (g/cm^3)	Shear-velocity (m/s)	Quality factor
Fill deposits	1.95	150	5
Holocenic Alluvium	1.95	300	10
Volcanic deposits and Pleistocene sediments	2.0	400	20
Pleistocene clays	2.1	600	50

- lower density of the recent alluvial deposits compared to the pre-Holocene sedimentary and volcanic formations (*bedrock*)

- different shear strength parameters

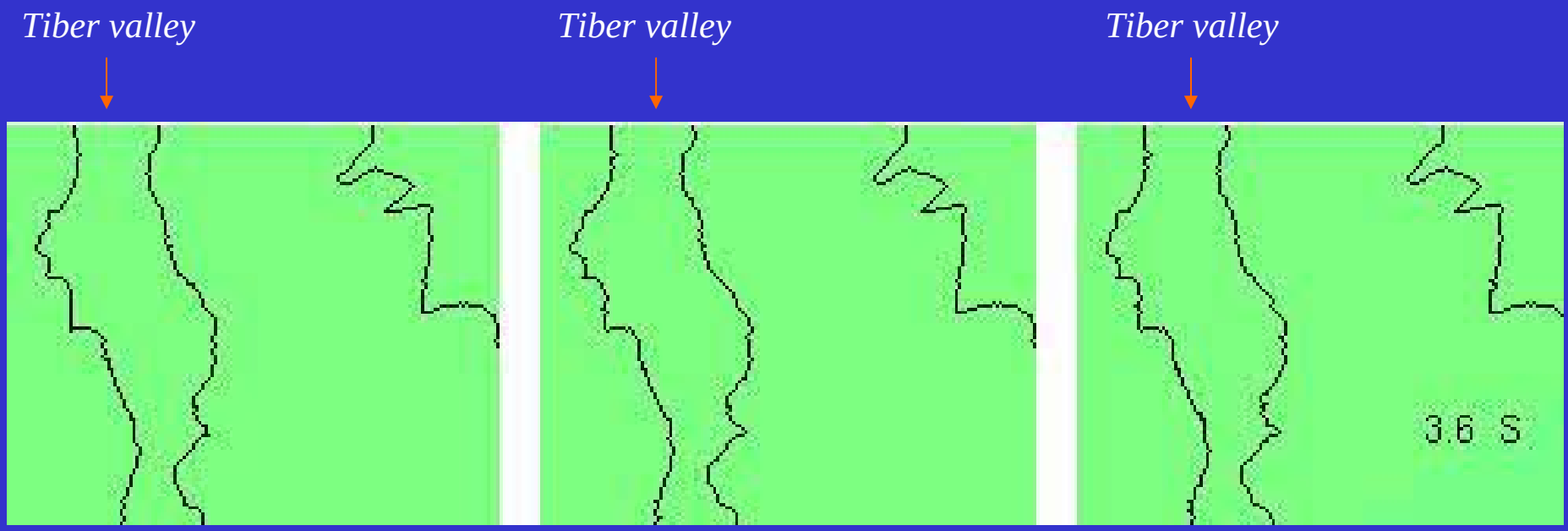
- low quality factor

SHARP TRANSITION BETWEEN

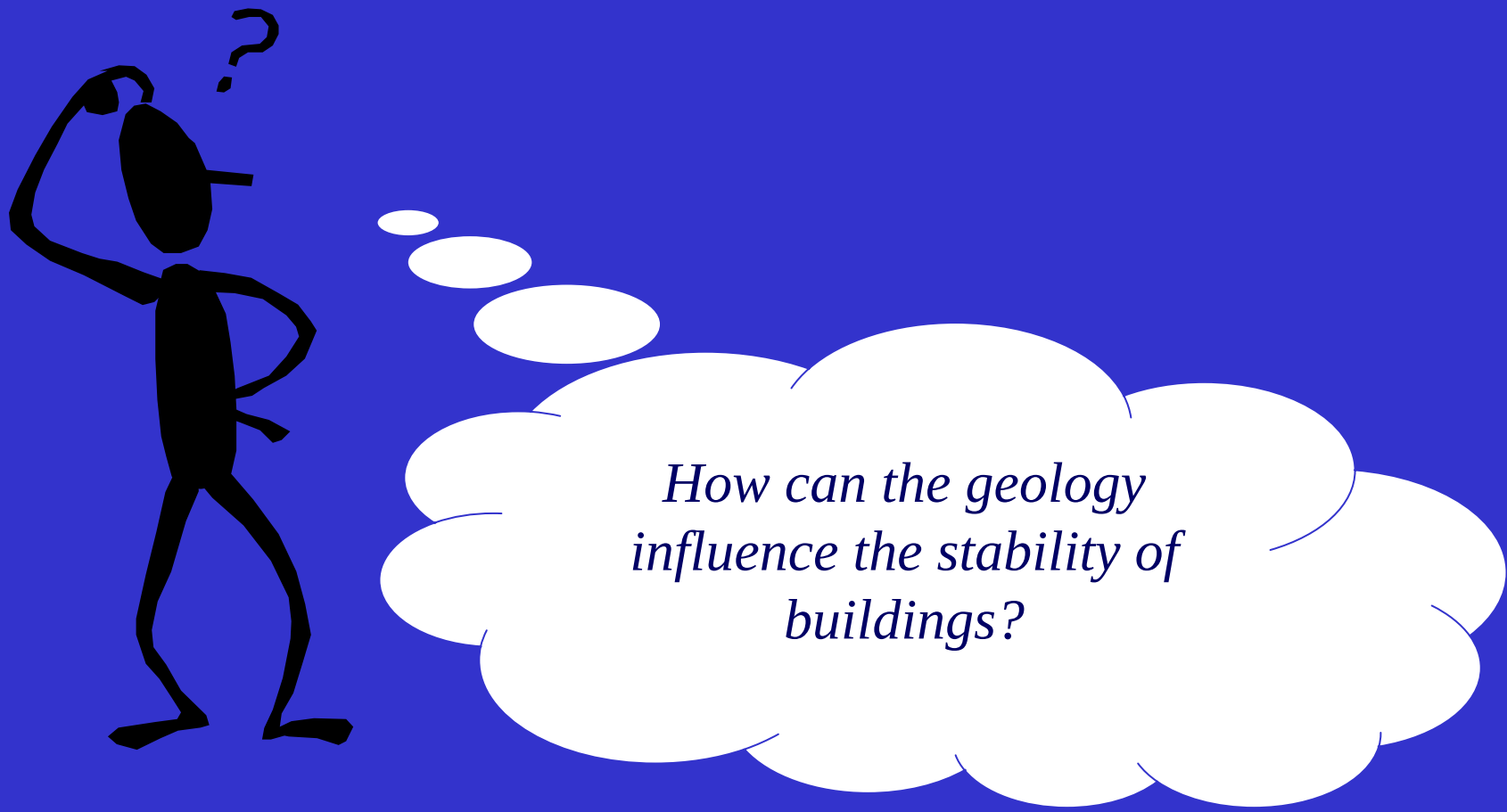
THE HOLOCENE ALLUVIUM

AND PLIO-PLEISTOCENE BEDROCK

0-1 Hz peak velocities for M=5.3 Alban Hills

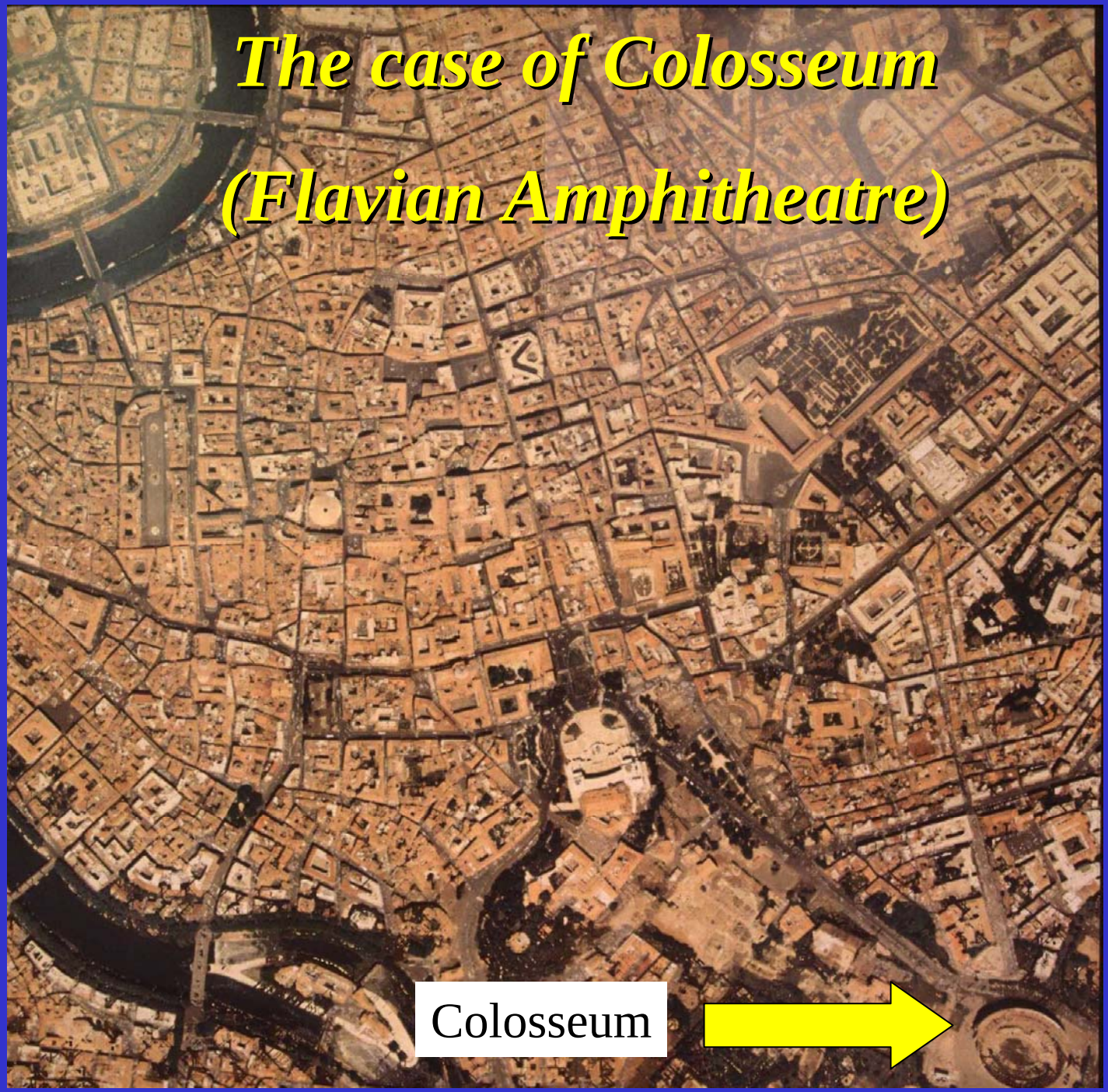


Olsen et al, 2005

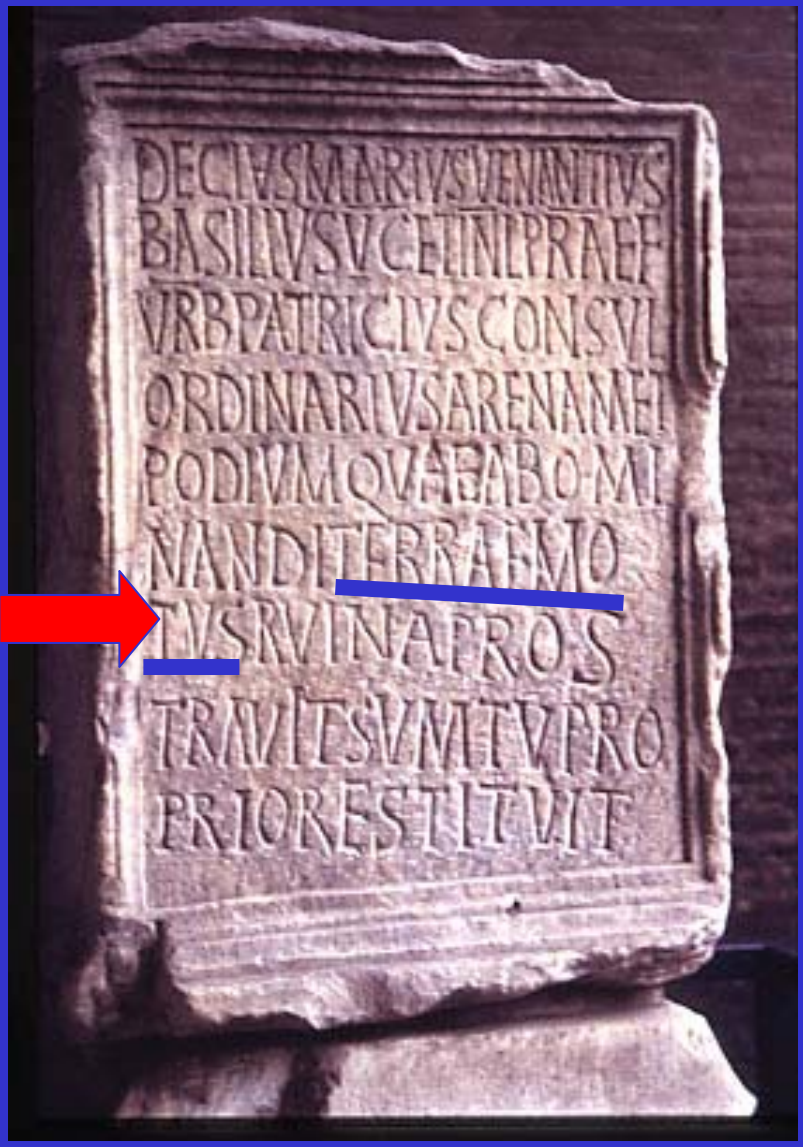

How can the geology influence the stability of buildings?

The case of Colosseum

(Flavian Amphitheatre)



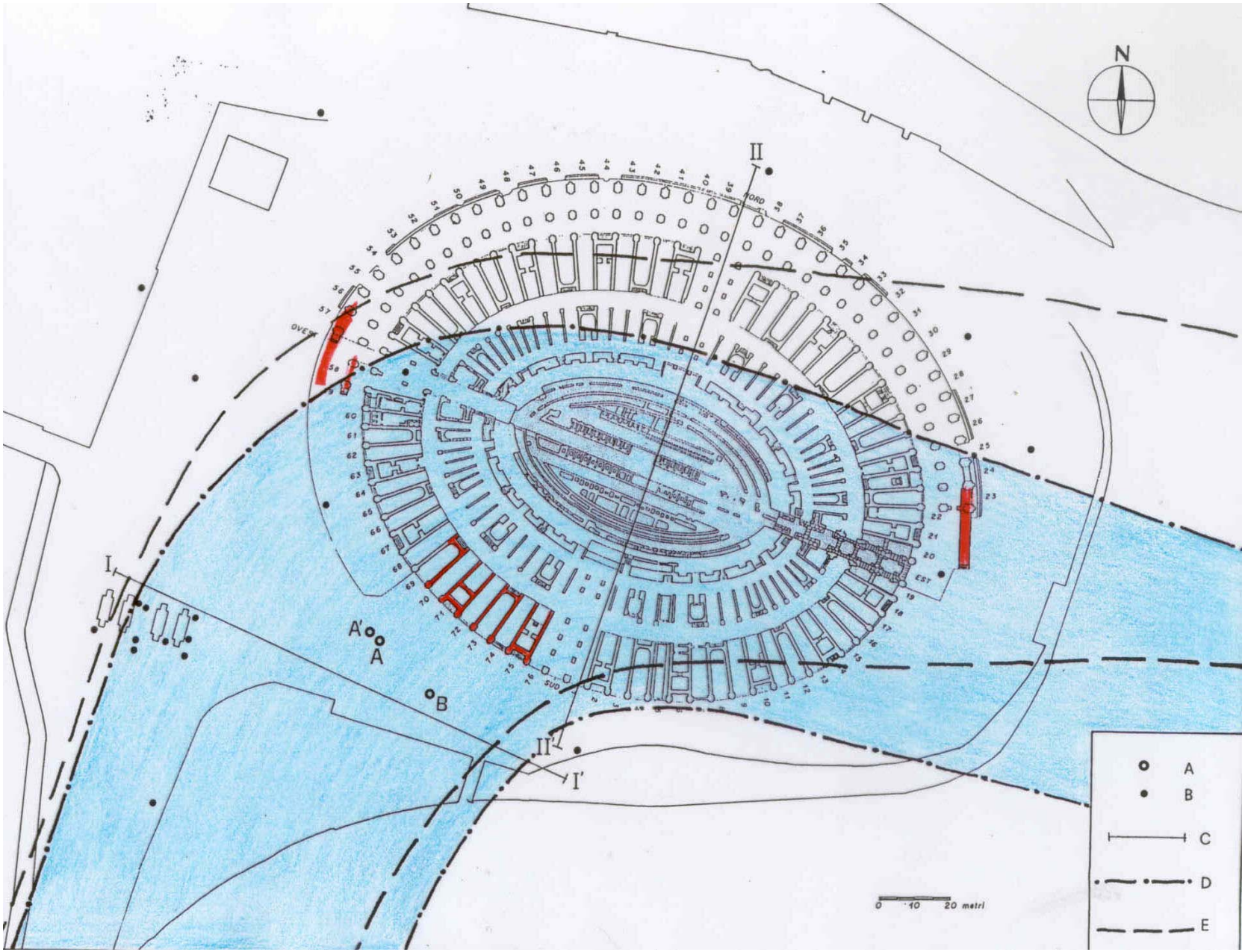

N


DECIVSMARIVSVENANTIVS
BASILIVSVCELINIPRAEF
VRBPATRICIVSCONSVL
ORDINARIVSARENAMET
PODIVMQVAEABOMI
NANDITERRAEMO
TVSRVINAFROS
TRAVITSVMTVPRO
PRIORESTITVIT

443 A.D.

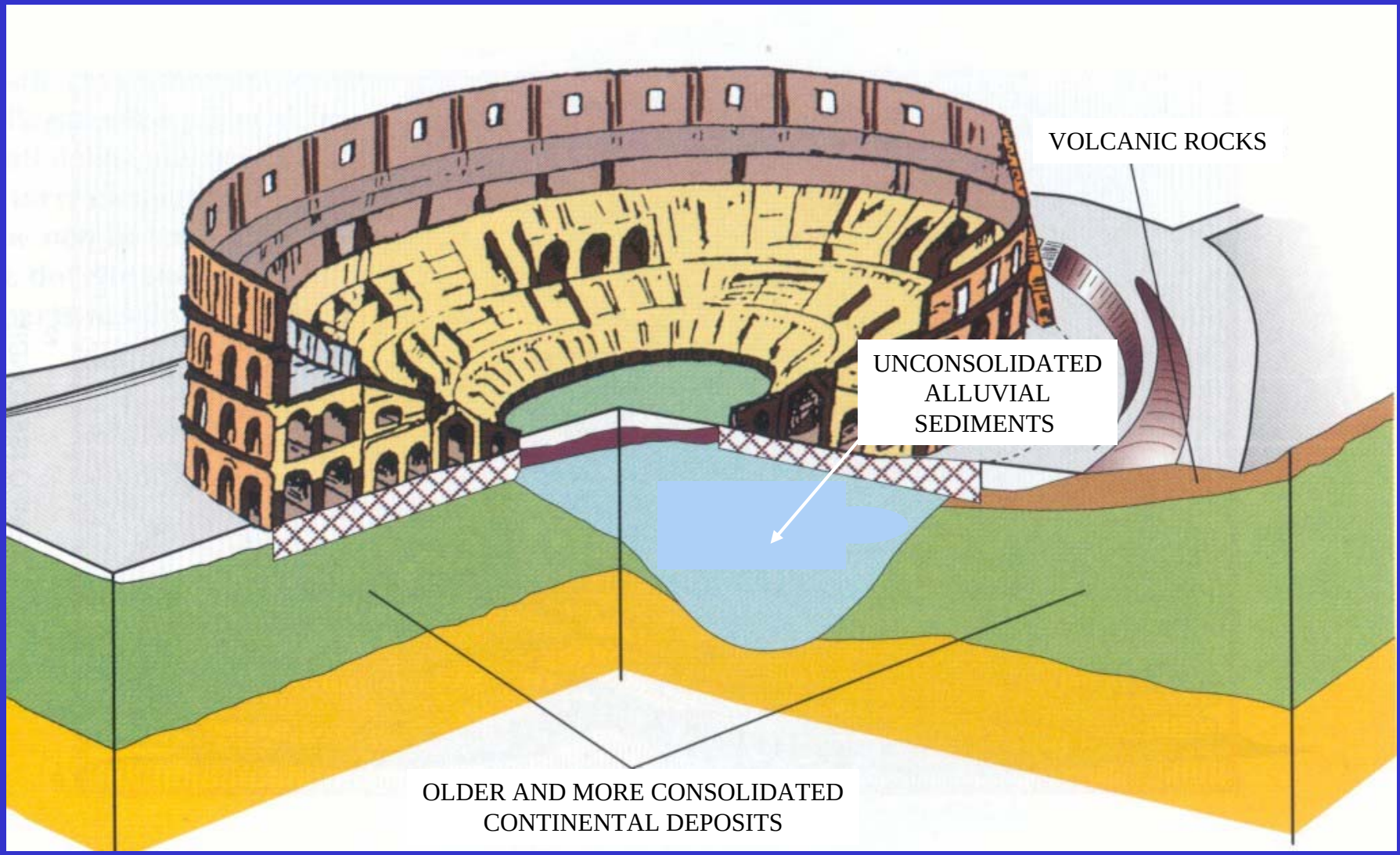

Which are the geologic factors responsible for the observed damages?

Plastic model of ancient Rome

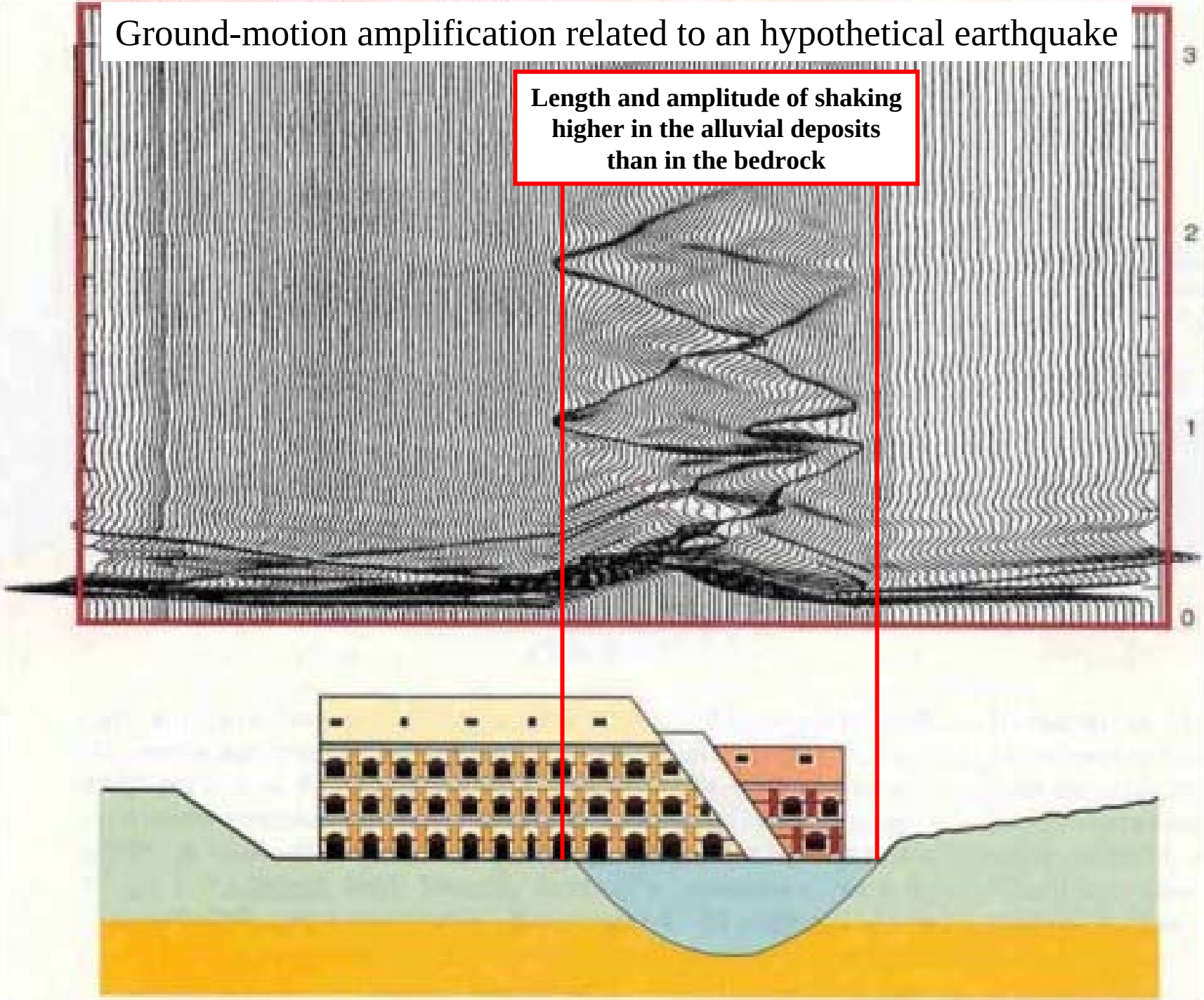

N
II
II'
I
I'
A'
A
B
OVEST
NORD
SUD
EST
0 10 20 metri
A
B
C
D
E

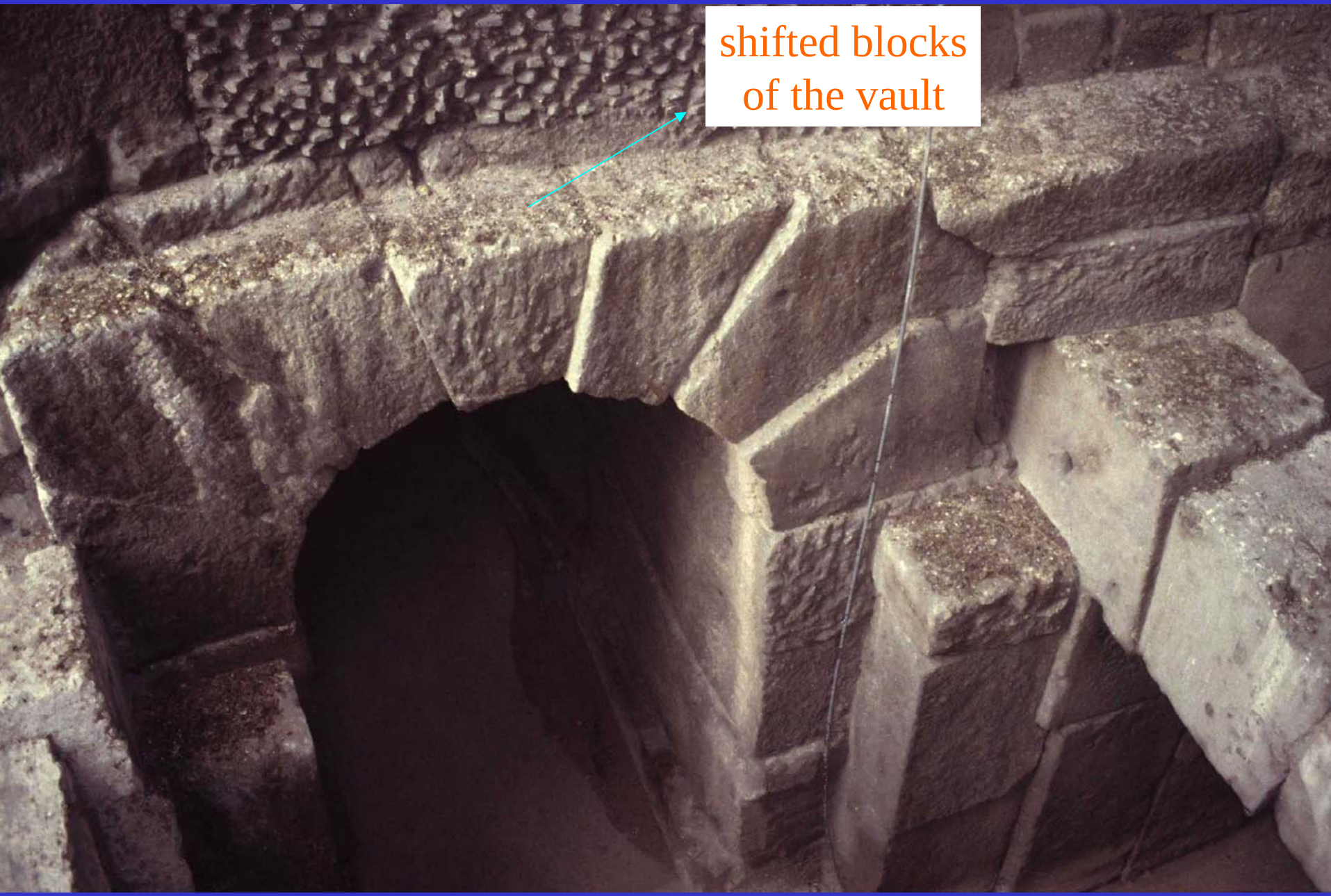
Aerial view of the Colosseum showing the correspondence between the Labican Valley and the southern part of the monument, heavily damaged

Cross-section of the Colosseum

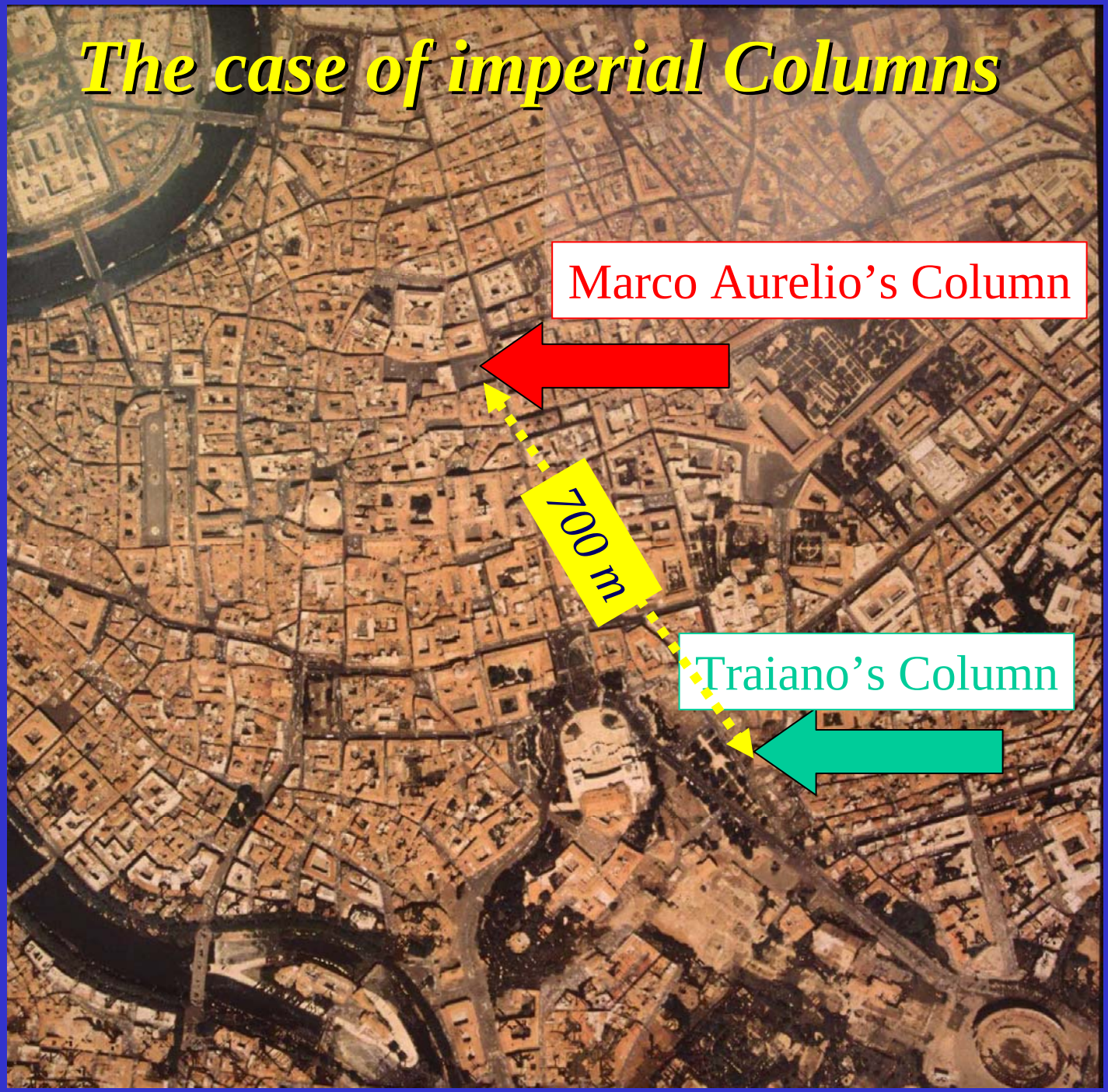


Ground-motion amplification related to an hypothetical earthquake




shifted blocks
of the vault

The case of imperial Columns



Yesterday….

Traiano’s column

Marco Aurelio’s column

… and today!

Traiano’s column

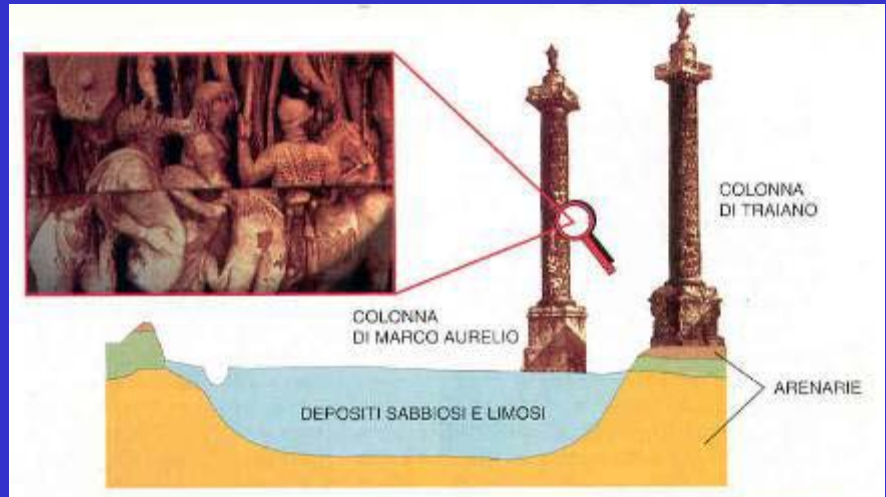
Marco Aurelio’s column

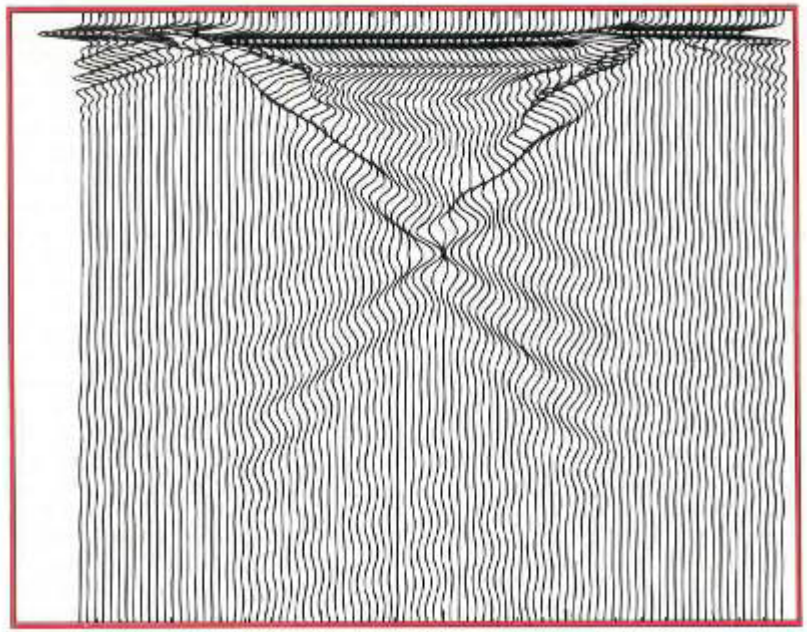
- similar height (h ~ 30m)
- similar material (marble)
- similar structure (18 marble cylinders)
- similar weight (about 1000 t)
- **foundations on different lithologies!**

- Different preservation of the two triumphal columns:
- **<u>Evident damage on the Marco Aurelio column</u>**

Different effects on the columns structures as a function of the different foundation deposits

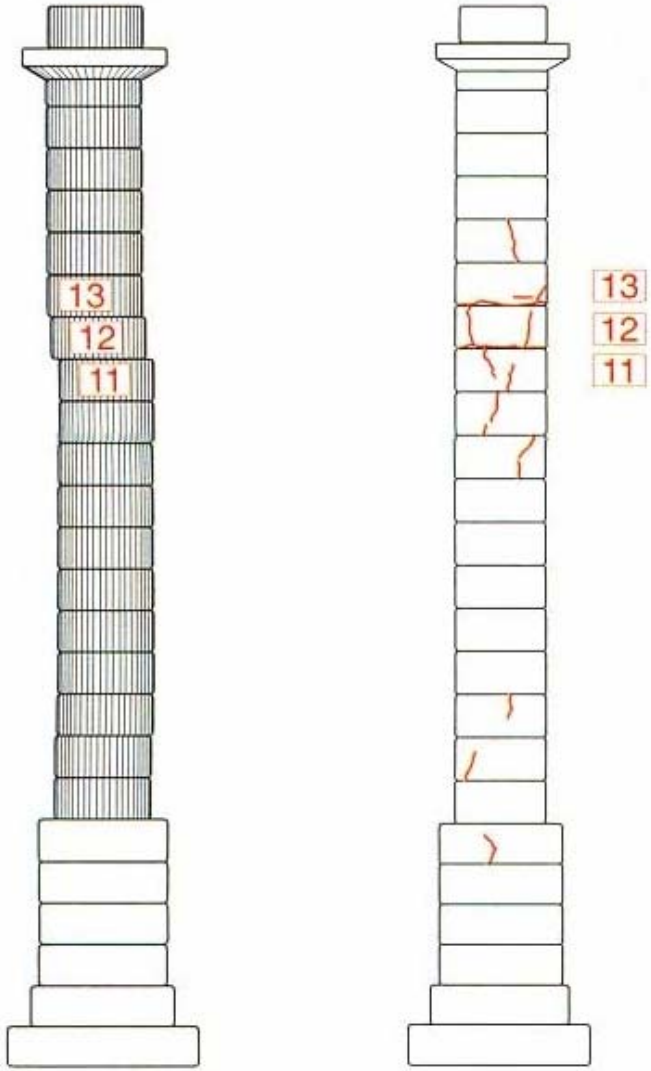
A model of ground-motion amplification related to an hypothetical earthquake indicates substantial soil movement below Marco Aurelio column, where seismic energy was “trapped” in the alluvial sediments



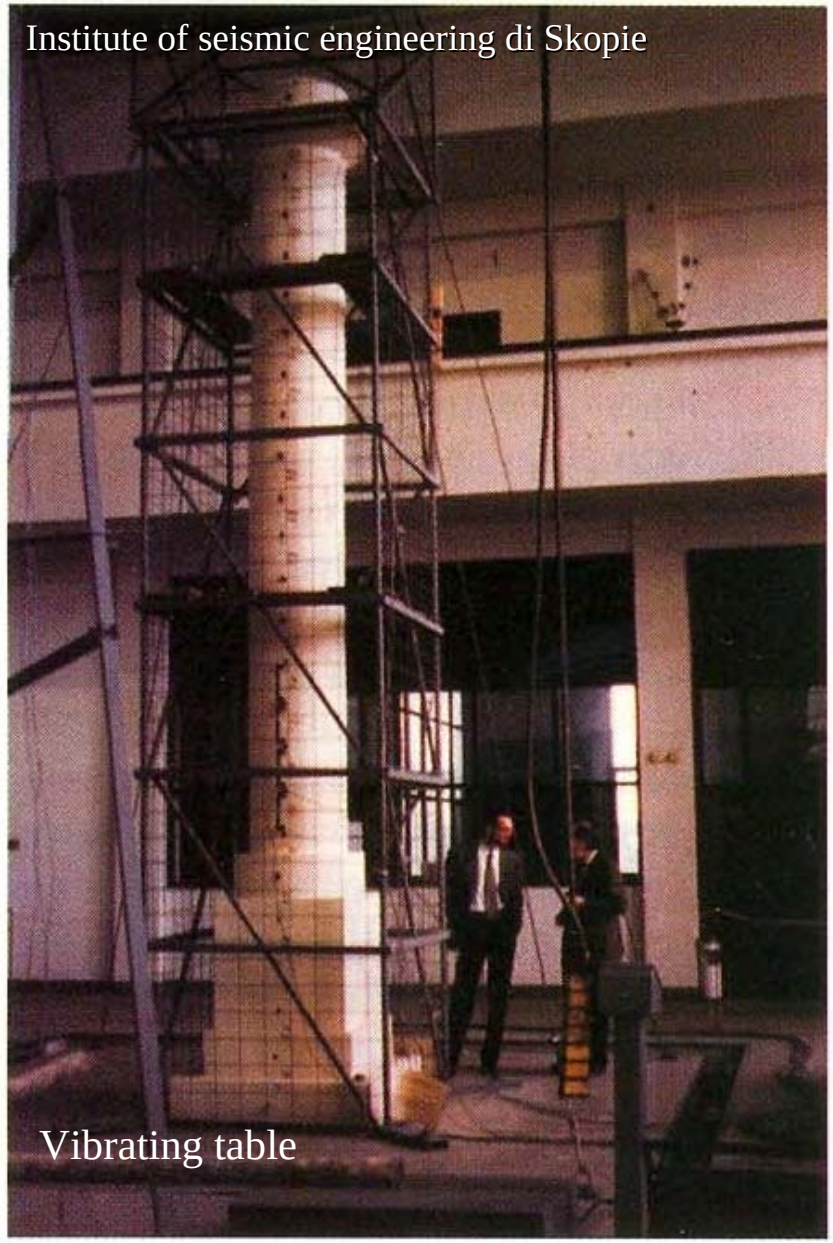


Marco Aurelio’s column: detail

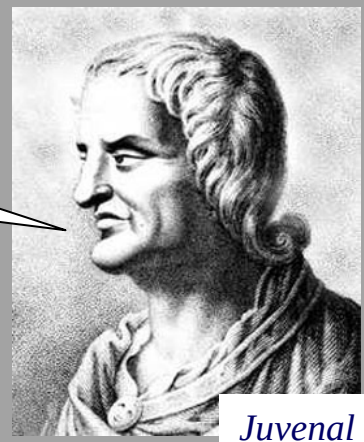
Model 1:6 of Marco Aurelio Column



A moderate soil horizontal acceleration causes on the model strong damages very similar to those observed today in the column



"We live in a city that is supported, more or less, by props!"



Juvenal

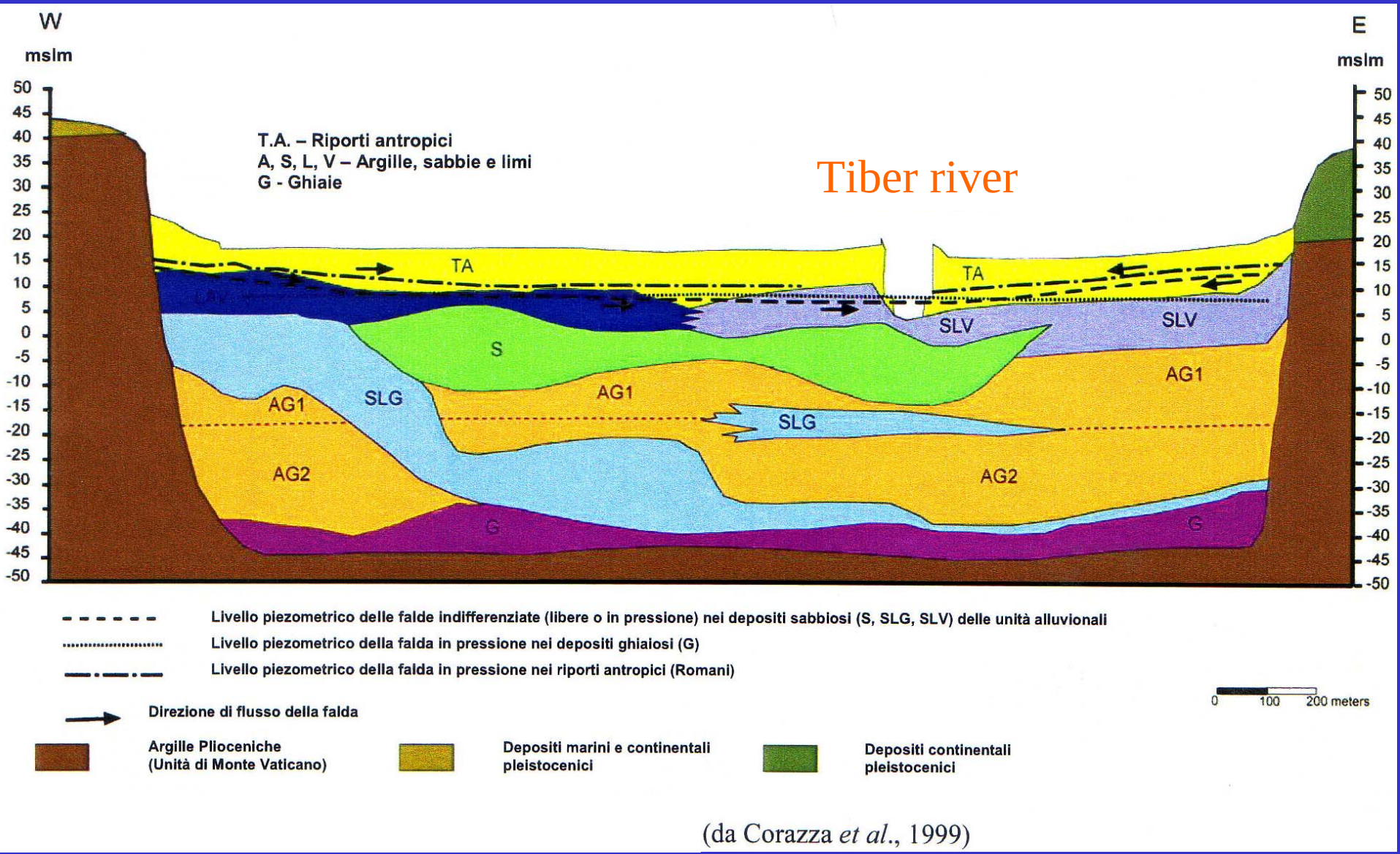
This is very similar to what happens in the modern world where cheap housing provide great profits but put residents at risk

Natural risks in the city of Rome

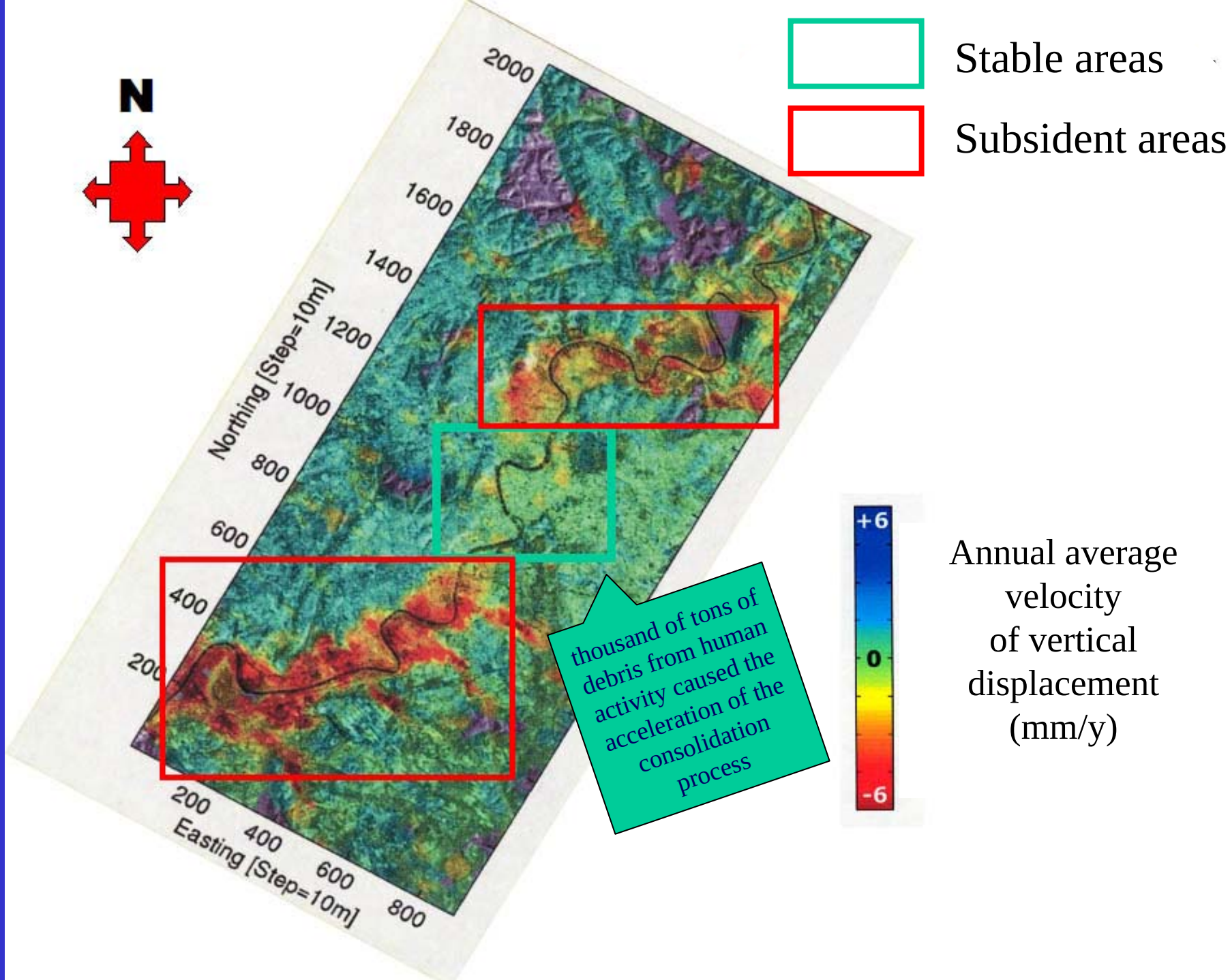
Source of Risk	Potentially interested areas	VAL evaluation for Rome	Characteristic time for the event	Probability that the event takes place in the next 100 yrs	Risk
Volcanic activity	Whole the roman area (gas→ Alban Hills)	VAL	Extremely high (gas→ frequent)	Close to 0 (gas→high)	Close to 0 (gas→ high)
Seismic activity	Area characterized by Holocene alluvium deposits	VAL/5	30 years (VI MCS)	High	Medium-high
Subsidence	Area characterized by Holocene alluvium deposits	VAL/5	Continuous phenomenon	Continuous phenomenon	Medium-high
Flood	Aniene basin	VAL/500	20 years	High	Medium-low

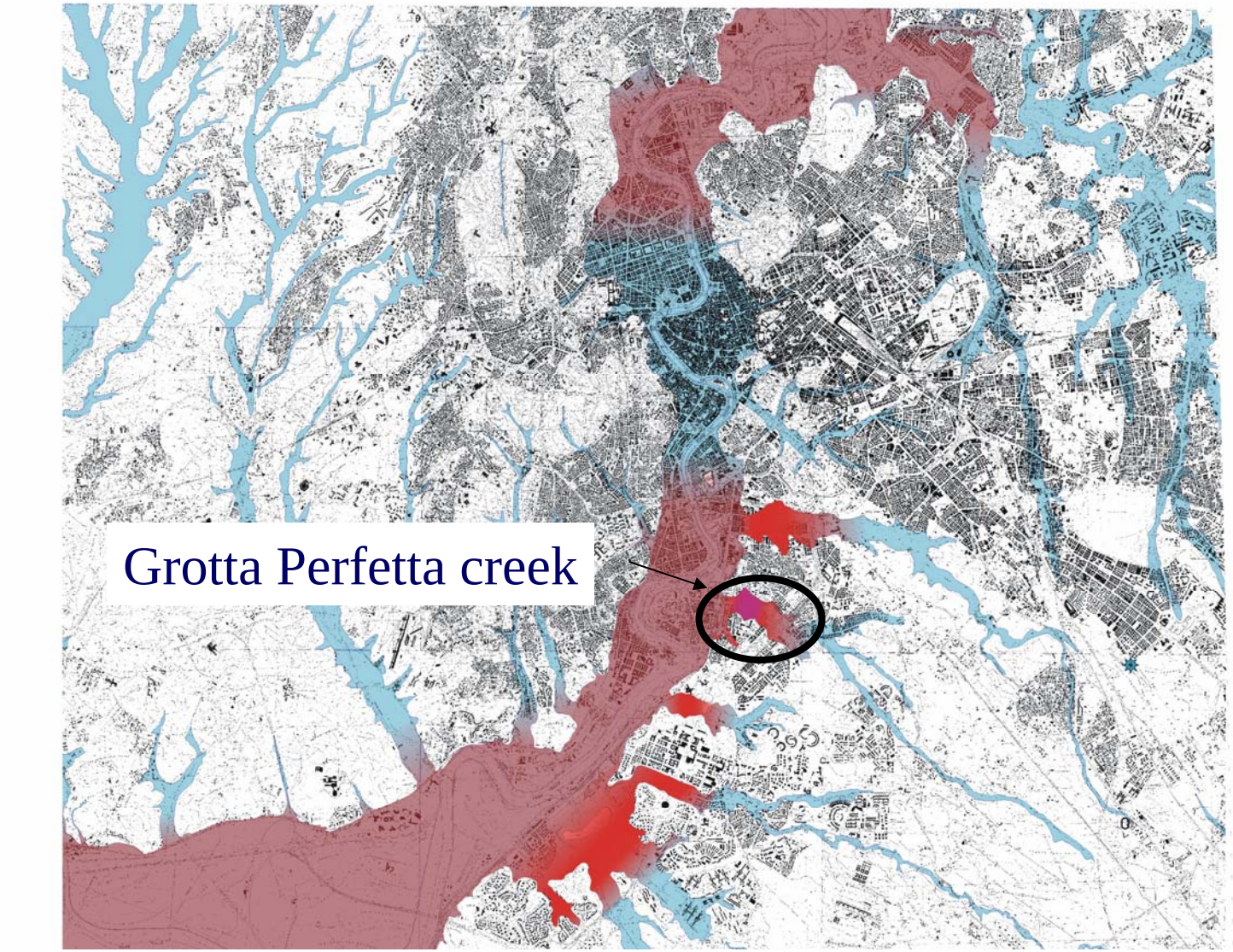
SUBSIDENCE

(downward relative moviment of the soil)

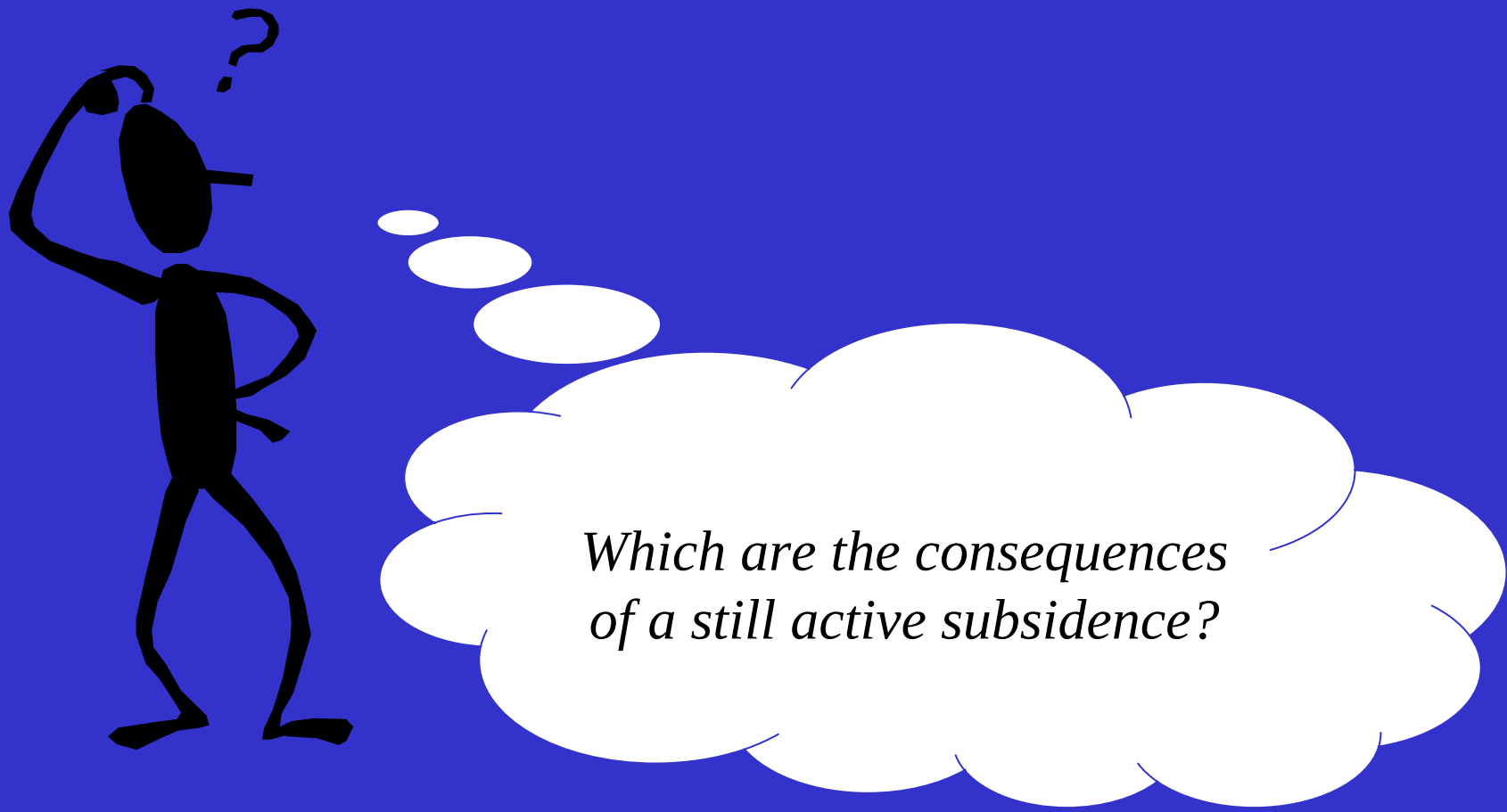


(da Corazza *et al.*, 1999)


N
2000
1800
1600
1400
1200
1000
800
600
400
200
Northing [Step=10m]
200
400
600
800
Easting [Step=10m]
Stable areas
Subsident areas
thousand of tons of debris from human activity caused the acceleration of the consolidation process
+6
0
-6
Annual average velocity of vertical displacement (mm/y)



% of subsidence


Which are the consequences of a still active subsidence?


cracks
pipes deflection
Via Giustiniano Imperatore

lost of verticality

Via Giustiniano Imperatore

separation of building components

Via Giustiniano Imperatore

Rome is the first italian city where prevention was applied so promptly in order to avoid possible catastrophic effects related to natural phenomena

Natural risks in the city of Rome

Source of Risk	Potentially interested areas	VAL evaluation for Rome	Characteristic time for the event	Probability that the event takes place in the next 100 yrs	Risk
Volcanic activity	Whole the roman area (gas→ Alban Hills)	VAL	Extremely high (gas→ frequent)	Close to 0 (gas→high)	Close to 0 (gas→ high)
Seismic activity	Area characterized by Holocene alluvium deposits	VAL/5	30 years (VI MCS)	High	Medium-high
Subsidence	Area characterized by Holocene alluvium deposits	VAL/5	Continuous phenomenon	Continuous phenomenon	Medium-high
Flood	Aniene basin	VAL/500	20 years	High	Medium-low

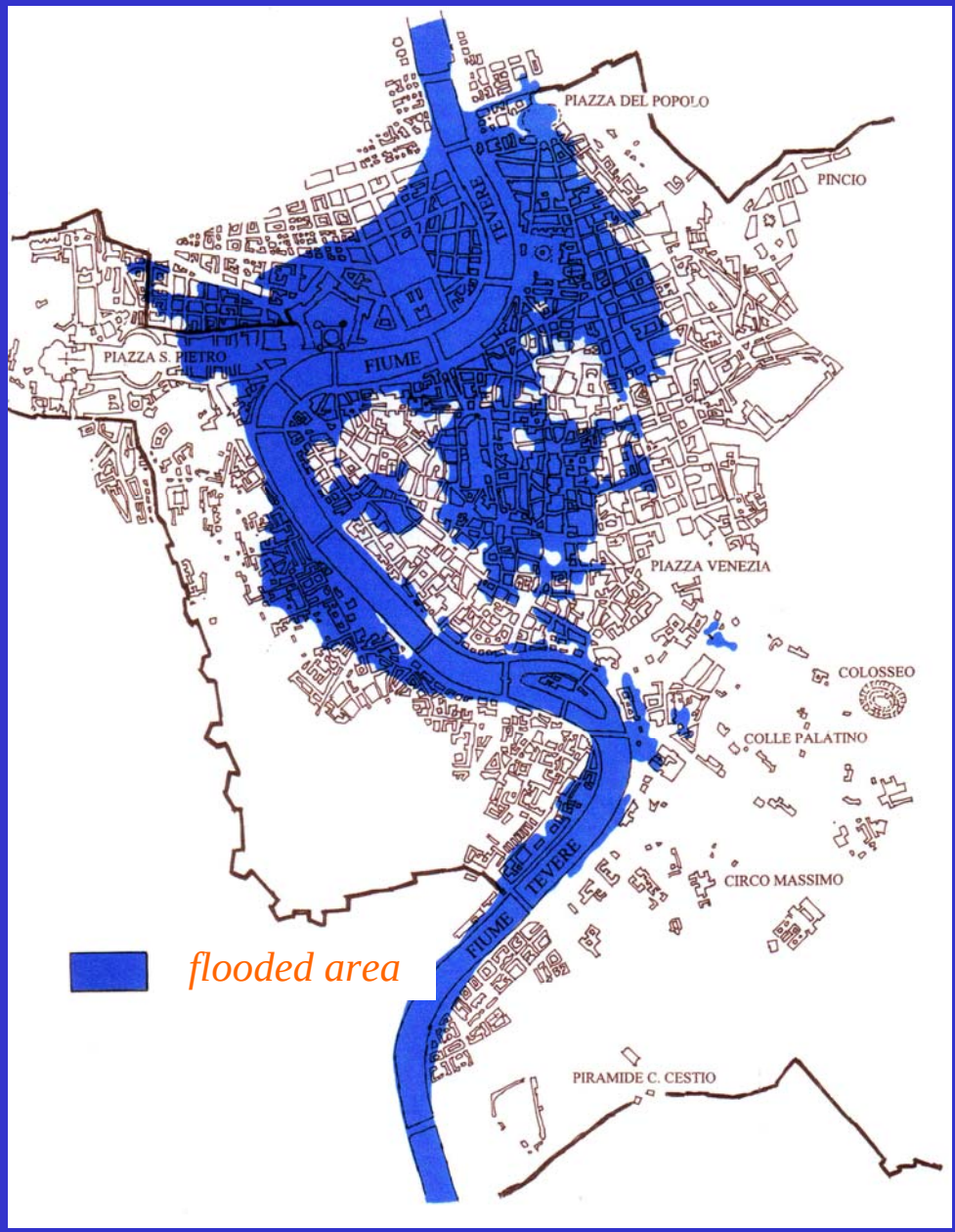
The Tiber Floods

Church of Santa Maria sopra Minerva (XIII century)

15 big and catastrophic floods!!!

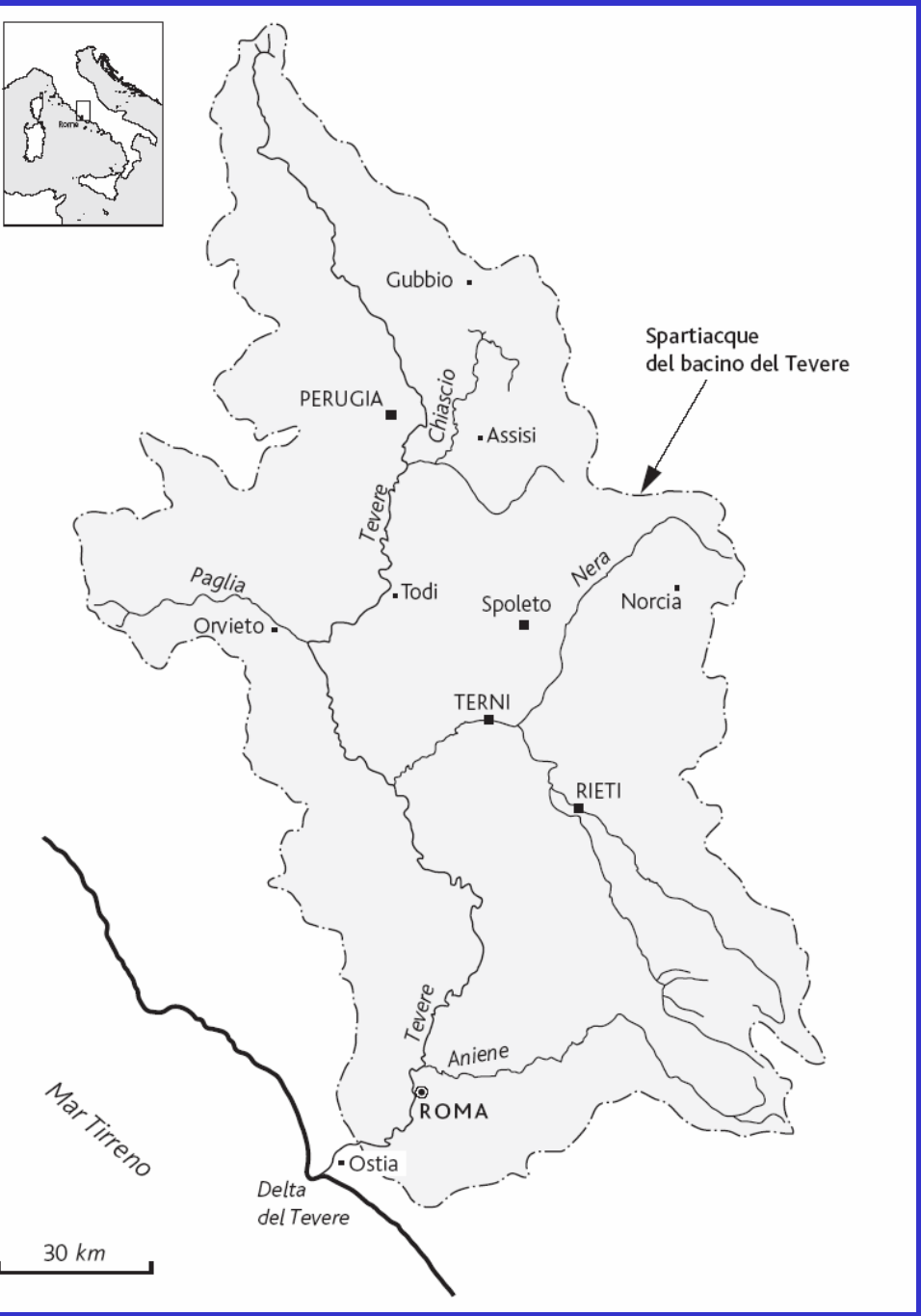
Pantheon, 1870

Piazza Navona, 1870


PIAZZA DEL POPOLO
PINCIO
TEVERE
PIAZZA S. PIETRO
FIUME
PIAZZA VENEZIA
COLOSSEO
COLLE PALATINO
TEVERE
CIRCO MASSIMO
FIUME
flooded area
PIRAMIDE C. CESTIO

1870 flood


Why so many floods
on the Tiber?



- largest basin in the Italian Peninsula

- 42 tributaries

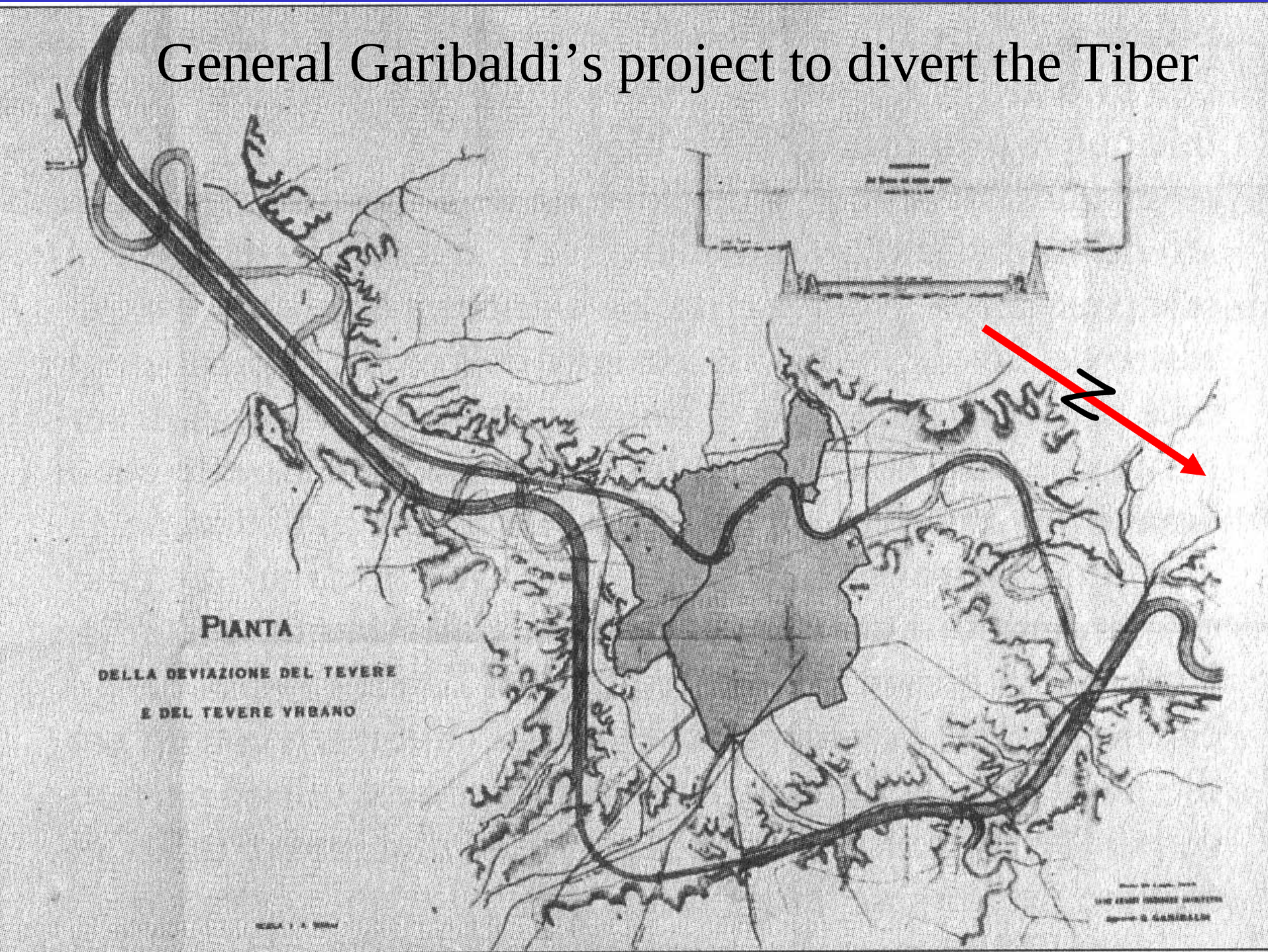
- source area characterized by

intense  *focused in a small area*

MUCH OF THE RUNOFF FROM THE TIBER RIVER BASIN ENTERS THE TIBER AND PASSES THROUGH ROME

MONITORING NETWORK

General Garibaldi's project to divert the Tiber



IL NUOVO GULLIVER ITALIANO

high walls along the riverbanks
to reduce the flood hazard

The Tiber today
Winter 2005 flood

The Tiber today
Winter 2005 flood

small arches → potential source of risk
("anomalous wave" from the jumping of coming water on the bridge)

The Tiber today
Winter 2005 flood

Conclusions

✓ The important link existing between the history of Rome and its geologic setting

✓ Ancient Roman engineers managed in a positive way the natural resources of the urban area and developed urban growth following rigorous rules, which contributed to the fortune of Rome for centuries

✓ However, roman engineers failing in not considering the basic issue of geologic underpinning before building the Colosseum!! Construction today in most of the world's cities suffers from the same problem: a lack of understanding of the geologic foundations below

✓ Looking at geological foundations upon which the city was built and examine records of what has occurred in the past could represent a suitable tool in future Rome urban planning

✓ No one has yet predicted an earthquake but it is possible to predict structural damage by an earthquake before it happens and find ways to mitigate damages

Conclusions

✓ An understanding of every city's geologic framework is not only interesting but also important in planning for the future of that city

✓ Understanding natural risks that threat large urban areas allow planners to best situate homes and civic buildings and to lower the risk from the natural events so common on our dynamic planet