


7th EUREGEO

Bologna | Italy | June 12th - 15th 2012

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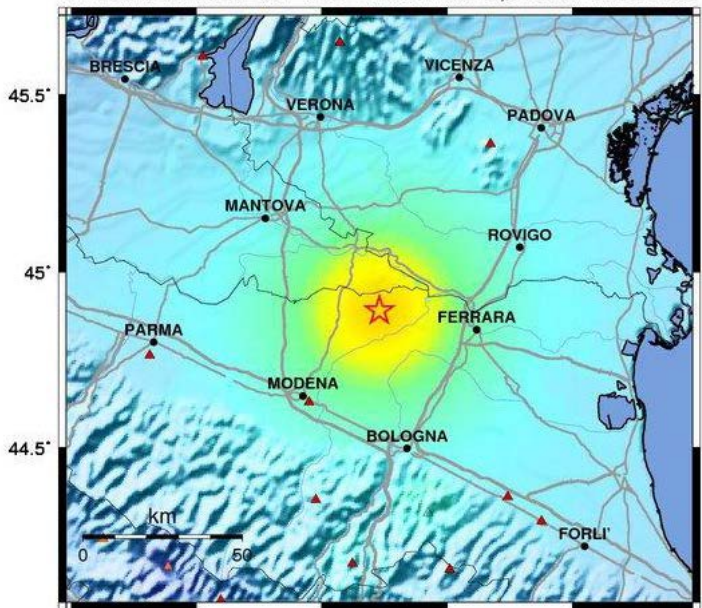
Sustainable
Geo-Management

Liquefaction effects observed in occasion of the 2012 May 20 earthquake in the Emilia plain

Luca Martelli



in coordination with:
DPC - Ufficio Rischio Sismico e Vulcanico
and the working group “Liquefaction 2012”



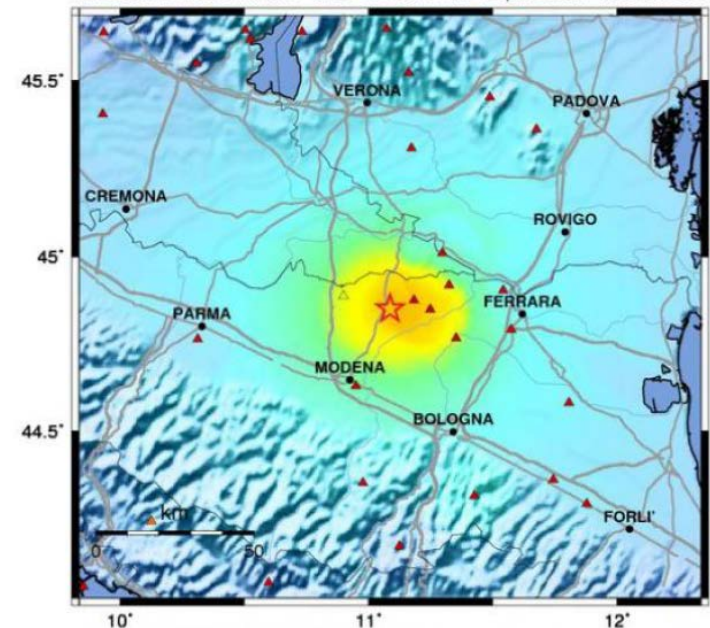
Map Version 9 Processed Sun May 20, 2012 06:44:21 AM GMT

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy	
PEAK ACC.(%)	<0.1	0.5	2.4	6.7	13	24	44	83	>156
PEAK VEL.(cm/s)	<0.07	0.4	1.9	5.8	11	22	43	83	>160
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al., 1999

On May 20, 2012 at 04:03 (local time) an earthquake $M_L=5.9$, 6.3 km depth, struck the Po Plain.

The epicenter (44.89°N , 11.23°E) was located east of Mirandola and north of Finale Emilia (Modena Province).



Map Version 1 Processed Tue May 29, 2012 07:35:43 AM GMT

PERCEIVED SHAKING	Not felt	Weak	Light	Moderate	Strong	Very strong	Severe	Violent	Extreme
POTENTIAL DAMAGE	none	none	Very light	Light	Moderate	Mod./Heavy	Heavy	Very Heavy	
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INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X+

Scale based upon Wald, et al., 1999

At 09:00 (local time) on May 29, 2012 another strong earthquake, $M_L=5.8$, 10.2 km depth, shook the Modena Plain.

The epicenter (44.85°N , 11.09°E) was located near Medolla (MO), 10 km WSW from the 20/5 main shock.

In some areas clear effects of liquefaction have been observed

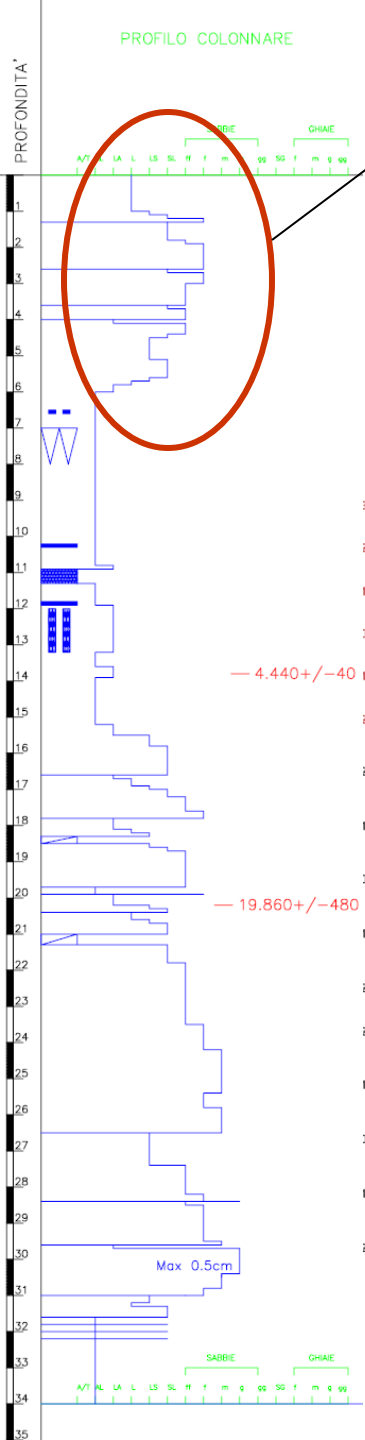


The term 'liquefaction' indicates various physical phenomena (cyclic liquefaction, cyclic mobility, flow liquefaction), affecting shallow saturated sand during strong earthquakes ($M > 5.5$).

The common element of these various phenomena is an increase and an accumulation of pore pressures that may cause a strong decrease in shear strength and a heavy loss of bearing capacity of the foundation soil.

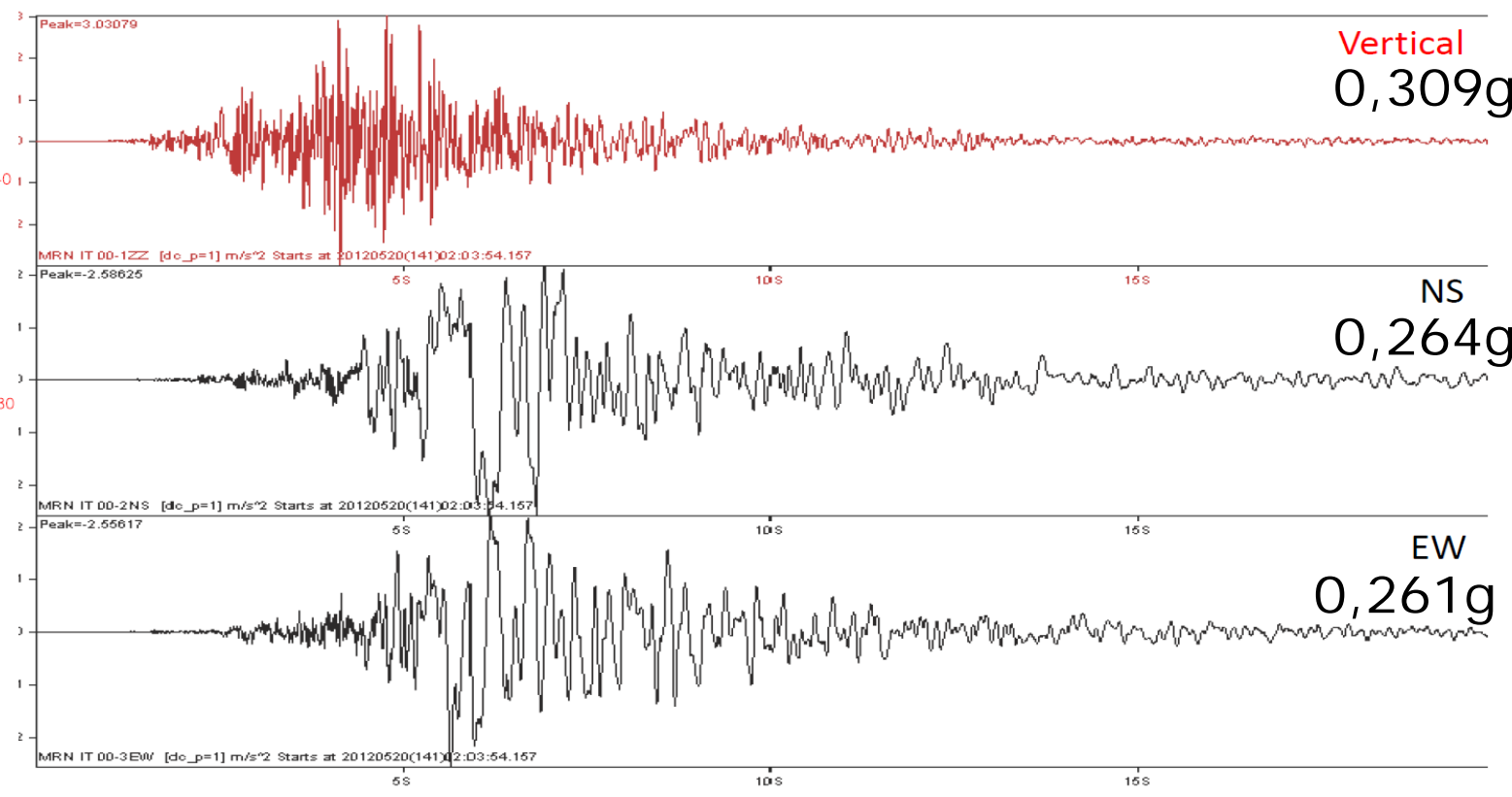
Liquefaction occurs if certain conditions are simultaneously verified:

- “susceptibility” of soil (predisponent factor): presence of uncemented and loose sand ($D_r < 60\%$) at depth < 15 m; depth of water table < 5 m; average diameter of grains $0.02 \text{ mm} < D_{50} < 2 \text{ mm}$; fine content (diameter $< 0.05 \text{ mm}$) $< 15\%$;
- “seismicity” (triggering factor): earthquake $M > 5.5$, $PGA > 0.15 \text{ g}$, duration of shaking $> 15\text{-}20 \text{ sec}$



Soil profile from bore-hole near S. Agostino:
 sandy silt and fine sand, < 4000 y, at depth between 1 and 6 m
 (susceptibility factor)

accelerometric records of the main shock $M_L=5.9$, May 20
 RAN Mirandola station (13 km from the epicenter)



triggering factor

In the Po Plain the morphology has been modified by man several times, especially for flood defense (elevation of banks) and stagnation in morphologically depressed areas (filling).

So, in some urban areas, artificial sandy fills are present.

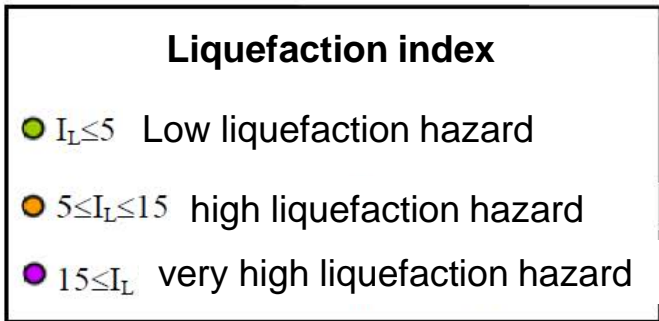
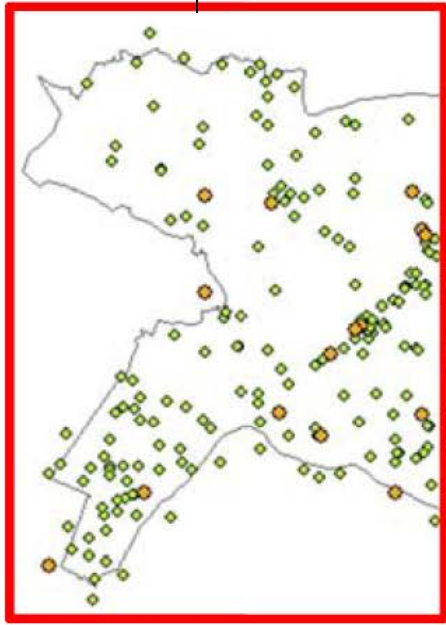
Furthermore, to avoid floods effects on the buildings, urbanization has occurred mainly on areas morphologically higher, i.e. on the banks and on abandoned riverbeds or on made ground areas.

On the basis of historical data (1570 Ferrara earthquake) and preliminary investigations (recent mapping on local seismic hazard for Territorial Plan), the area between Novi di Modena and Ferrara was known as susceptible to liquefaction



Fracture between S. Carlo and S. Agostino, courtesy of Ferrara University

Area of Ferrara Province where liquefaction effects have been observed



Local map of liquefaction hazard

From “seismic microzonation for the Territorial Plan of the Ferrara Province”
V. Fioravante and D. Giretti, Ferrara University

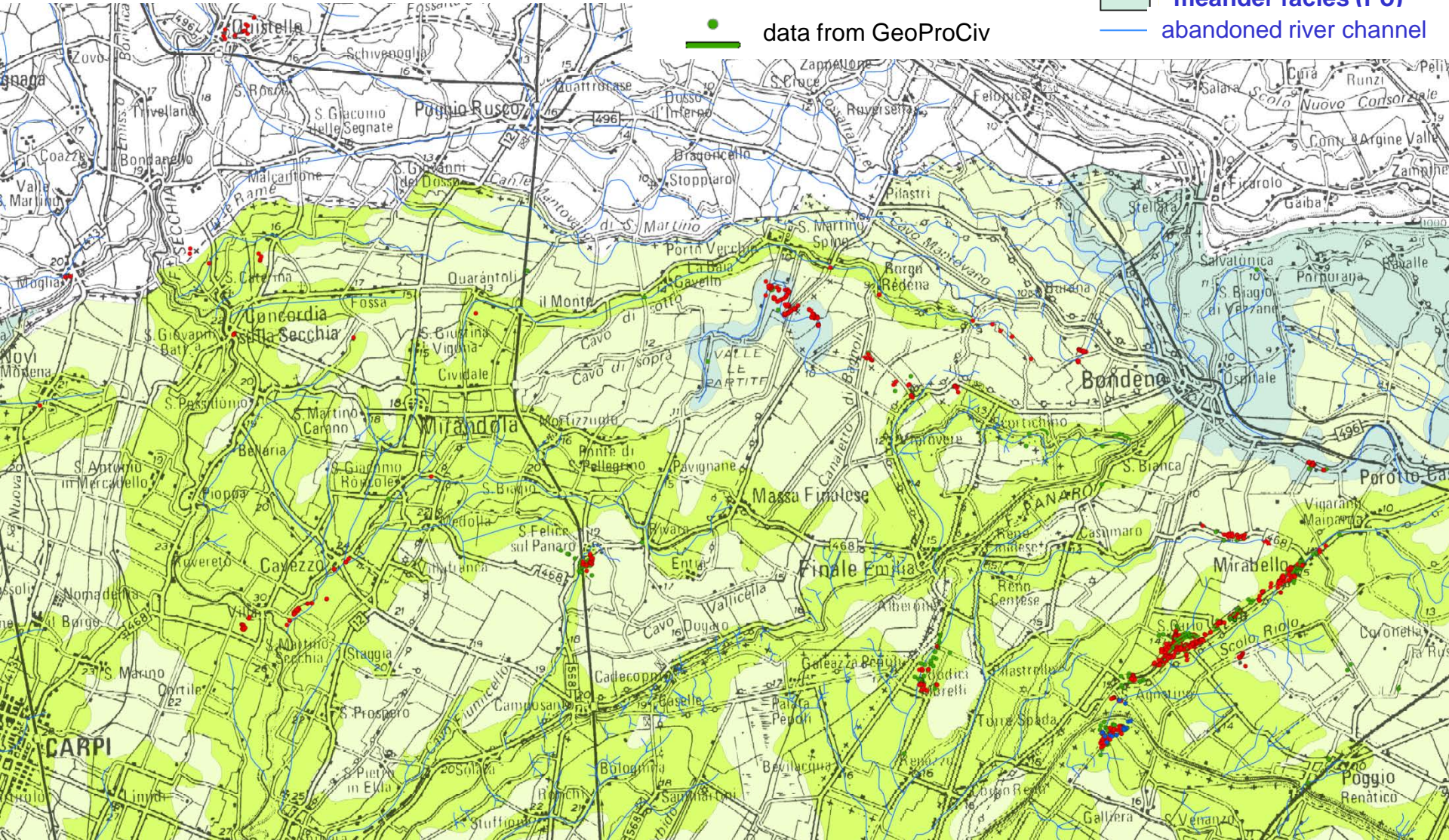
To evaluate the effects of liquefaction and to verify the stability of buildings and networks most affected by this phenomenon (towns of S. Carlo and Mirabello, in the province of Ferrara), RER and DPC have established a multidisciplinary team consisting of geologists, civil engineers and geotechnical engineers of the Regional Authority, DPC, Province of Ferrara, engineering departments of Ferrara and Florence Universities, GeoProCiv, and professional geologists and engineers.

This working group is coordinated by the regional Geological, Seismic and Soil Survey and DPC – Ufficio Rischio Sismico e Vulcanico.

Also geologists and engineers from CNR (IGAG, IMAA, IAMC), Urbino and Basilicata Universities and Technical University of Milan are involved in this study.

Map of observed liquefaction effects; updated June 7, 2012

- data from STB Reno
- data from STB Affluenti Po
- data from GeoProCiv
- channel-leave facies
- alluvial plain facies
- meander facies (Po)
- abandoned river channel



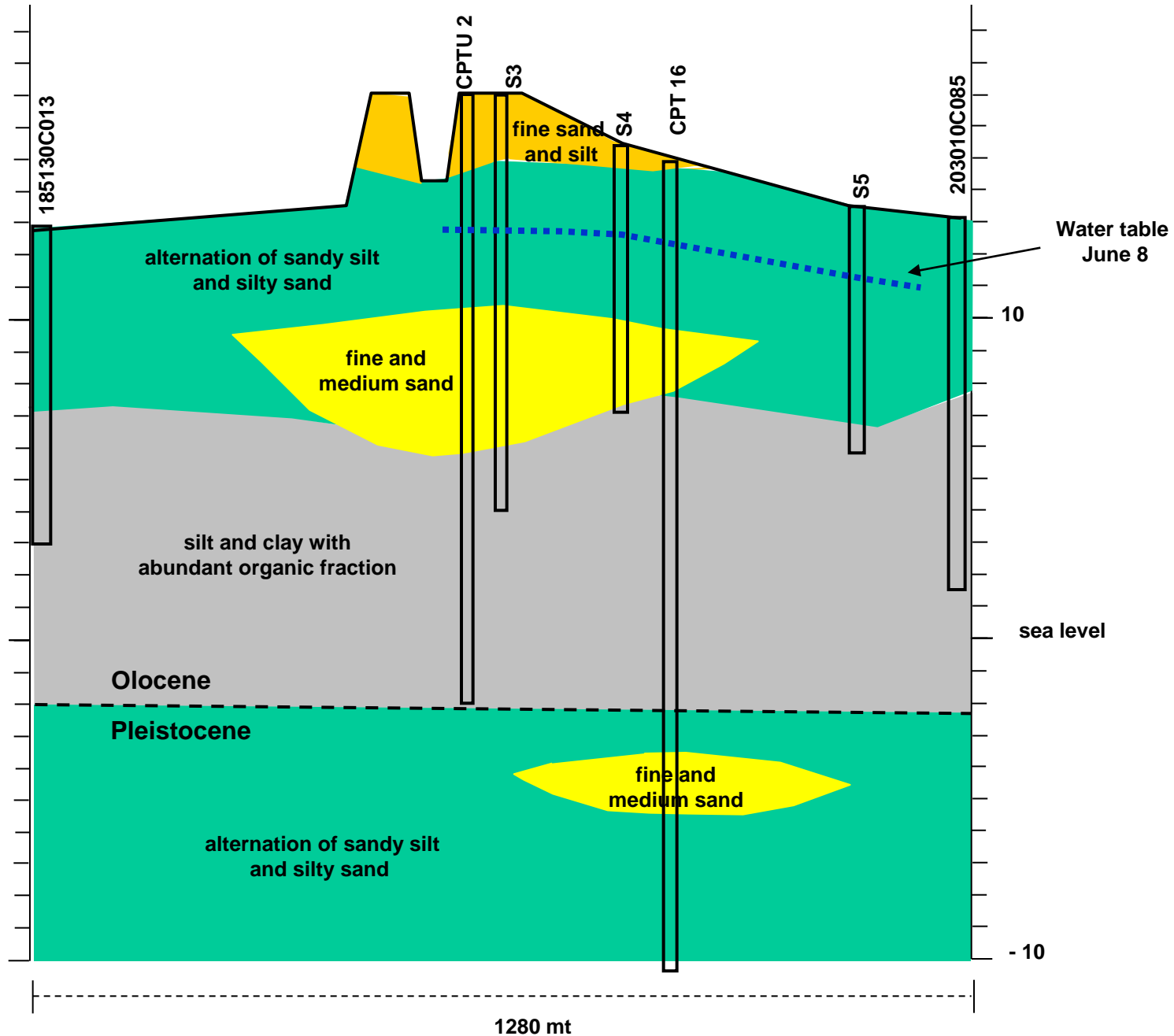


The main effects of liquefaction were observed in correspondence of abandoned river channels



- liquefaction sites observed in S. Agostino and Mirabello
- data from STB Reno
 - data from STB affluenti Po
 - data from GeoProCiv
 - channel-levee facies
 - alluvial plain facies
 - abandoned river channel

geological cross-section WNW-ESE through S. Carlo (south area)



during the major shocks a rising of the water table of over 3 m was observed

Main observed effects:

- sand volcanoes
- sand boils
- vents
- cracks
- bulges
- lateral spreading
- ground settlements
- subsidence

S. Felice sul Panaro, city stadium
courtesy of Ferrara University



S. Carlo, via VIII marzo



S. Carlo, via Rossini



S. Carlo, via Rossini



sand volcanoes in the plain W of S. Carlo



crack in the field W of S. Carlo
courtesy of Florence University



Mirabello, uplift of the floor of the sidewalk
courtesy of Florence University



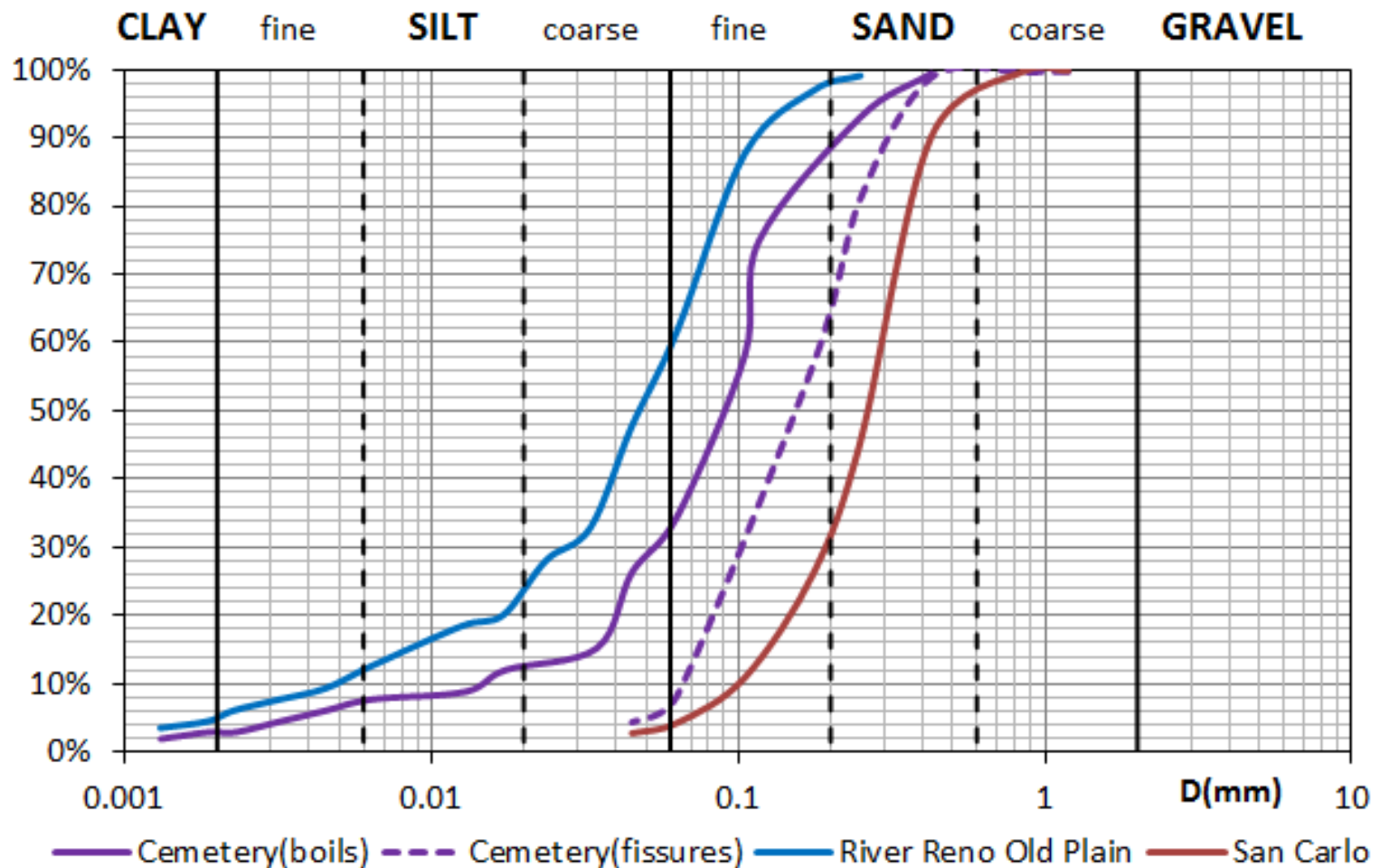
Mirabello, crack in the industrial zone
courtesy of Florence University

perpendicular to a fracture with
rising sand a trench has been dug
S. Carlo, courtesy of Ferrara University



fracture





Grain sizes of sands sampled at the surface of S. Carlo

Courtesy of Urbino University

PRELIMINARY CONCLUSIONS

As a result of preliminary observation and analysis of the site and with respect of constructions' stability, no evidence of rotation or sliding of building was observed, neither loss of bearing capacity of foundation systems, mainly superficial.

In general, subsidence of the buildings appears to be limited and uniform under constructions. Only in some cases most significant failures, accompanied by rotations (always moderate) have been observed

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Thanks for your attention!

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