# The geologic support to subsidence analysis in Emilia-Romagna alluvial plain

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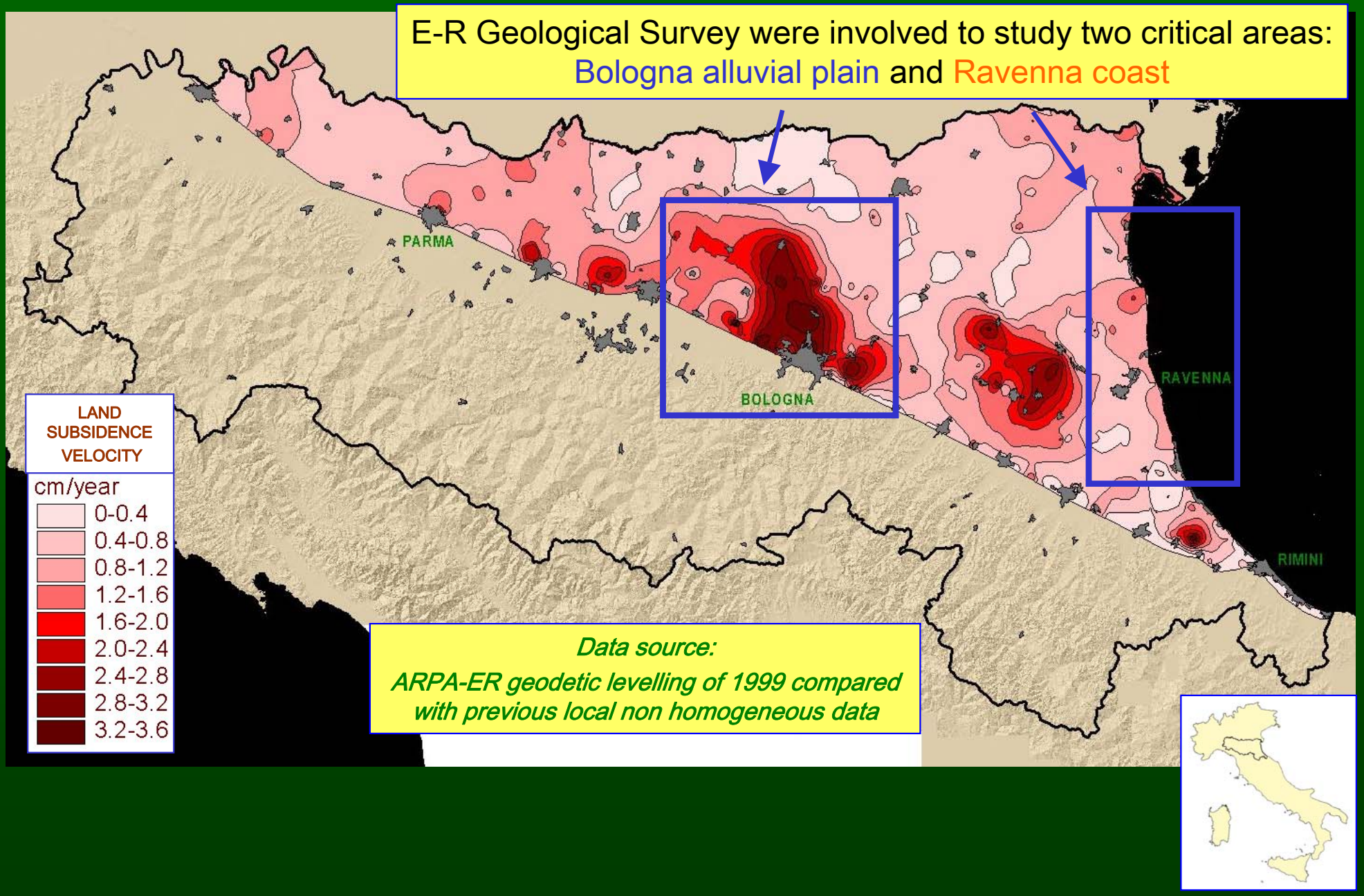
# SUBSIDENCE IN EMILIA-ROMAGNA ALLUVIAL PLAIN:

## The land-subsidence velocity map *(ARPA-ER monitoring network)*

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# THE PROJECTS

Study of the Reno River alluvial fan to realize a hydrologic and subsidence model for water resource management

*Regione Emilia-Romagna, Provincia di Bologna, Comune di Bologna, Autorità di Bacino del Fiume Reno, ARPA-ER, Hera Spa.*

Anthropogenic Land Subsidence due to groundwater withdrawal in the Emilia-Romagna coastland

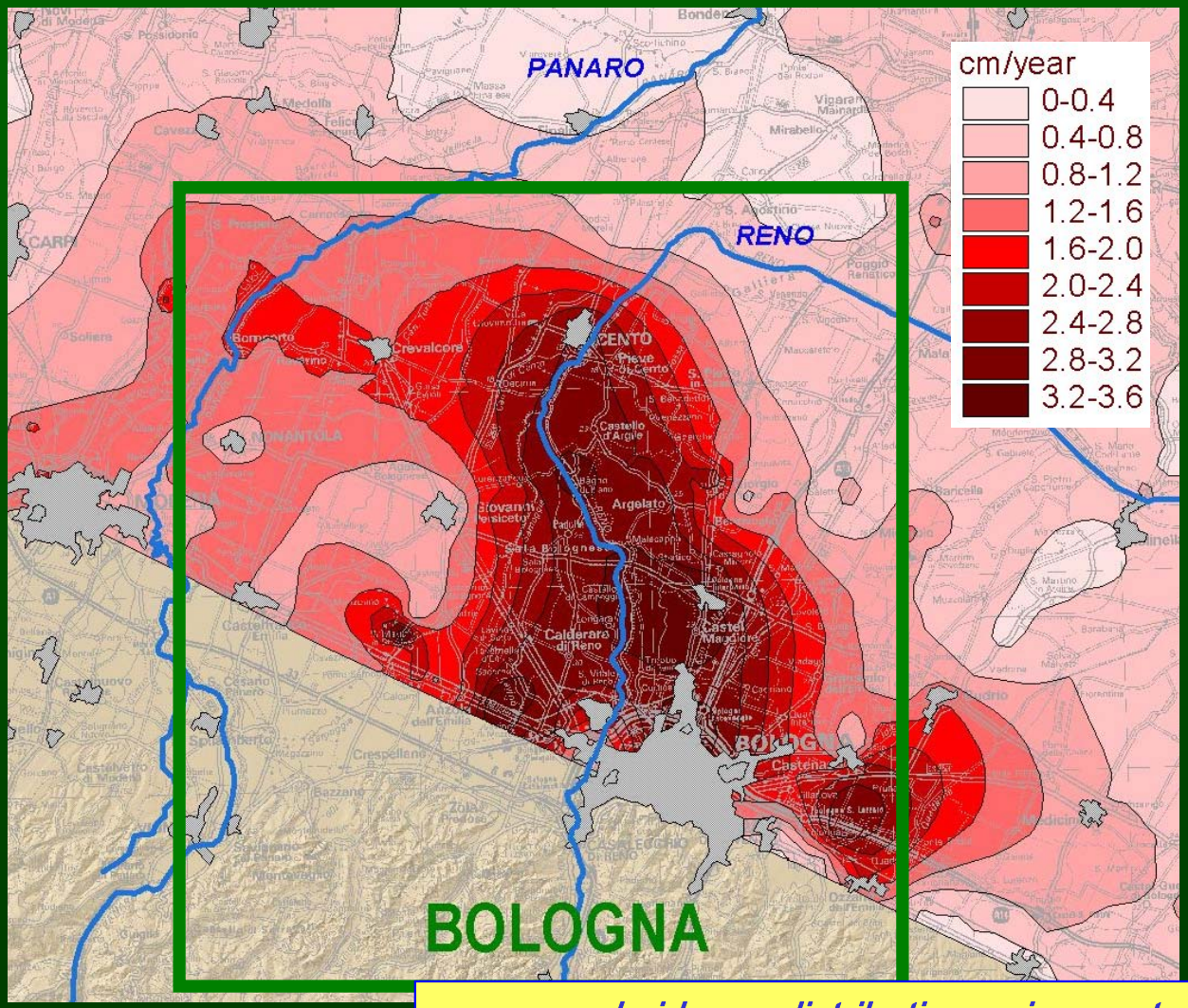
*ENI-AGIP, Comune di Ravenna, ARPA-ER, Servizio Geologico, Sismico e dei Suoli RER, MED Ingegneria Srl*

Angela Angelina Project for aquifer pressure maintenance (Ravenna)

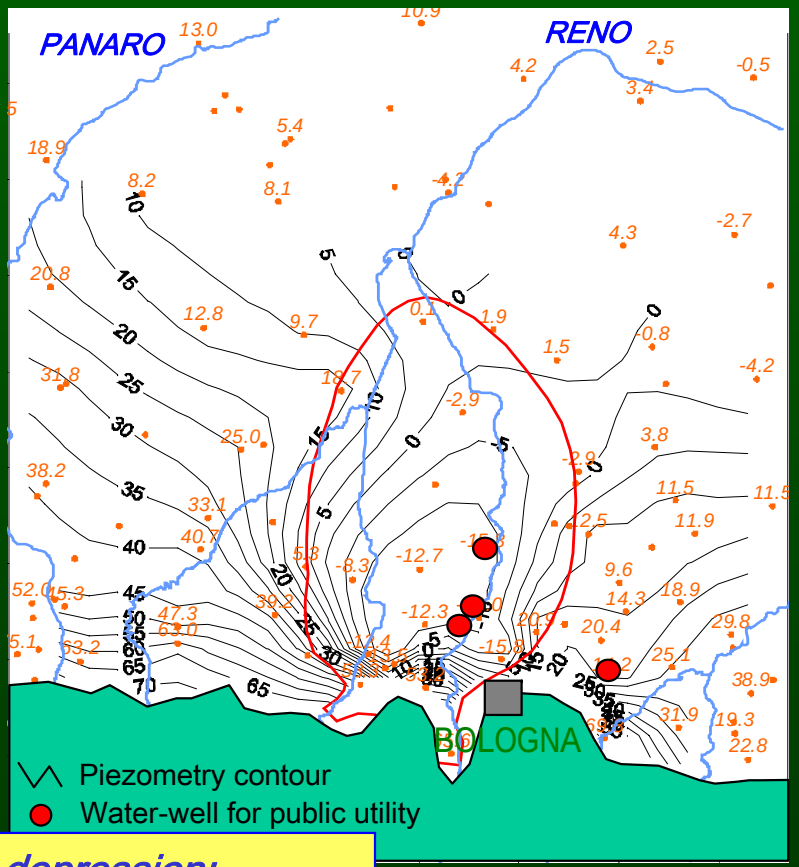
*ENI-AGIP, Regione Emilia-Romagna, Provincia di Ravenna, Comune di Ravenna*

# SUBSIDENCE IN BOLOGNA AREA:
## Groundwater pumping from the Reno River alluvial fan and plain

Detail of land-subsidence velocity map near Bologna
(subsurface alluvial fan of Reno River at the valley mouth)




Piezometry drop at the drinking water wells of Bologna city




*subsidence distribution - piezometry depression:*
*relationships between groundwater pumping and land lowering*

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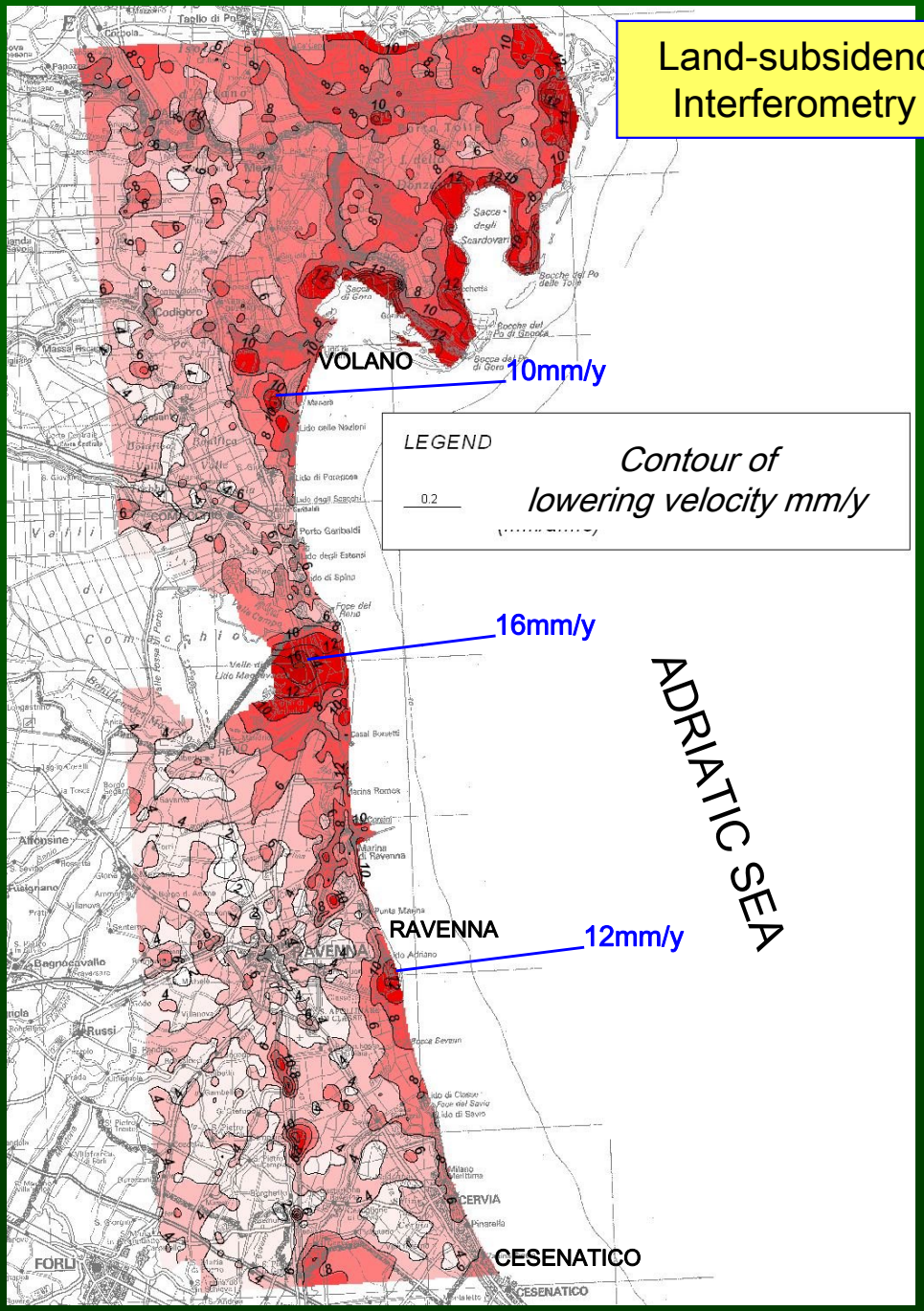
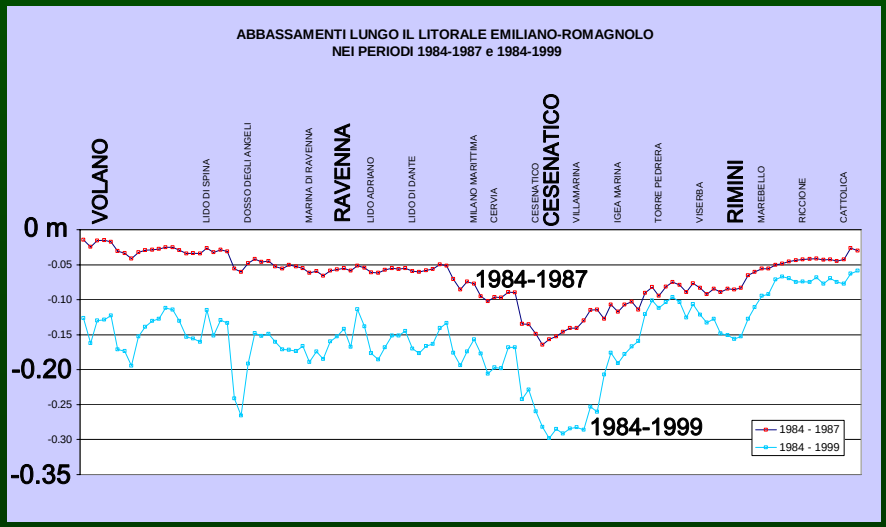
# SUBSIDENCE IN THE COASTAL AREA: the knowledge *(data ARPA-ER)*




Land-subsidence velocity map based on Interferometry - SAR data (1992-2000)


ARPA-ER monitoring network 1999

Land-lowering diagram from the coast levelling line

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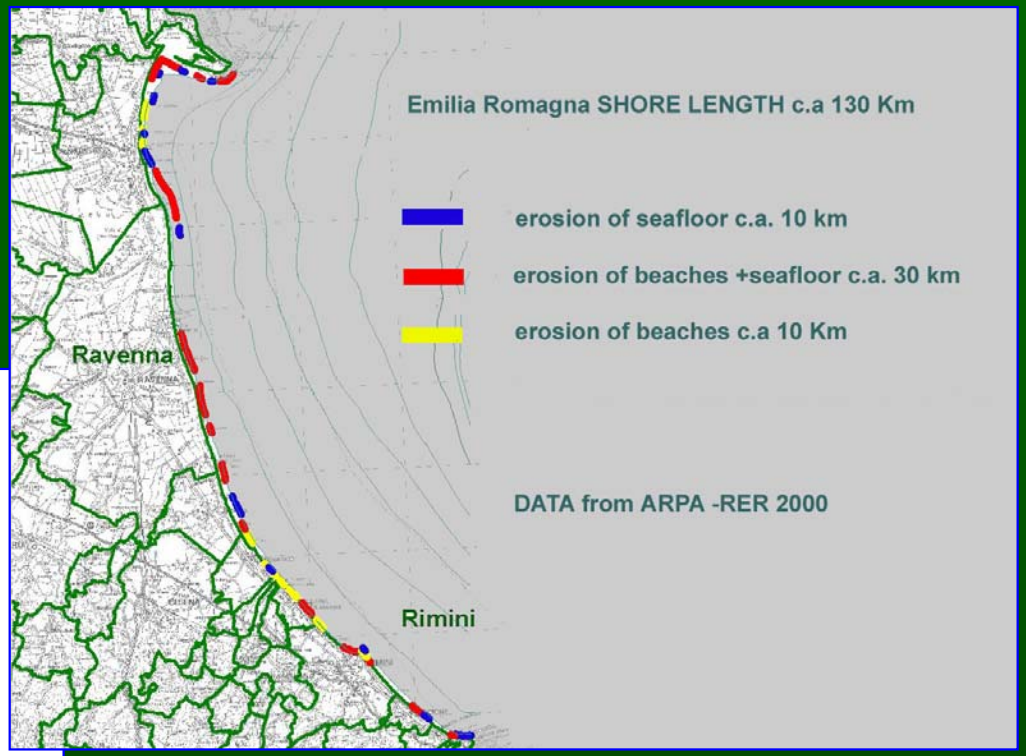
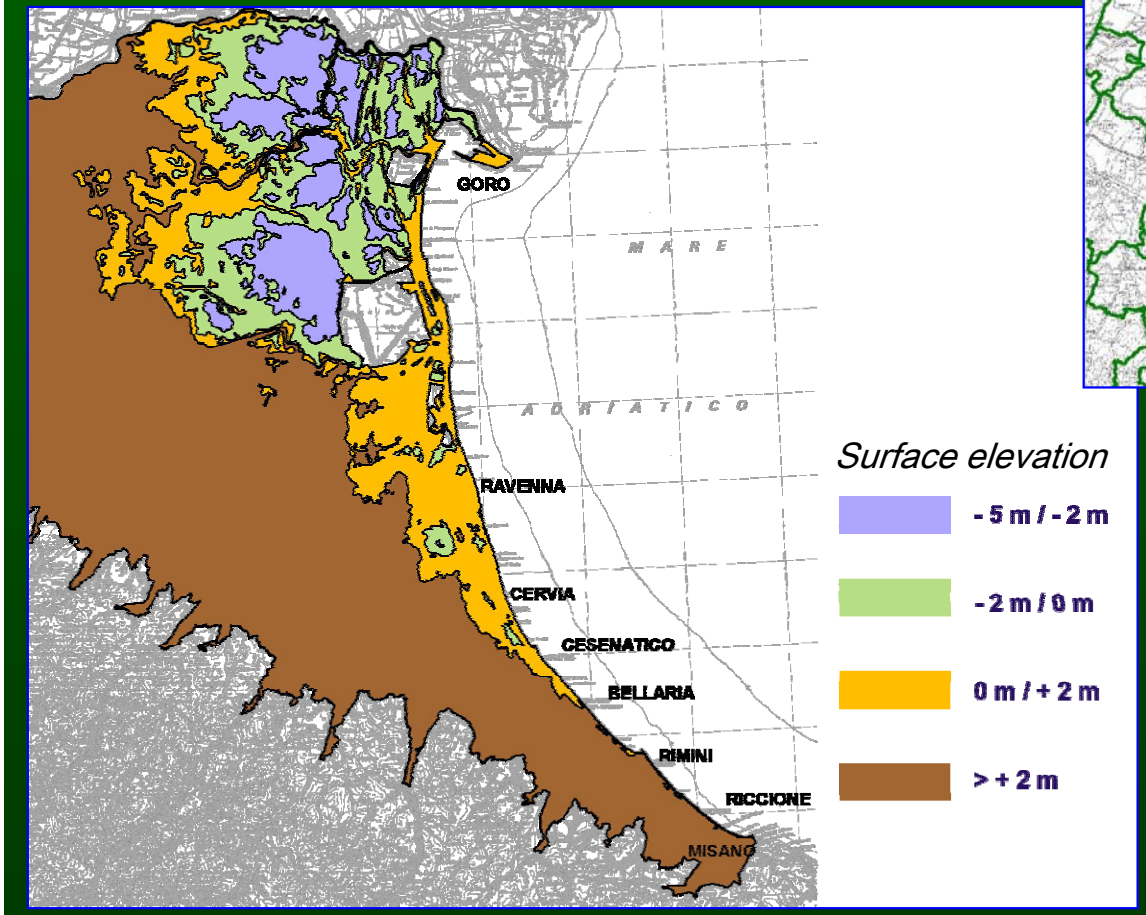
# SUBSIDENCE IN THE COASTAL AREA: the risks

The 40 % of the coast line is affected by sea erosion




A great part of the coastal plain is below sea level and exposed to flooding and sea inundation

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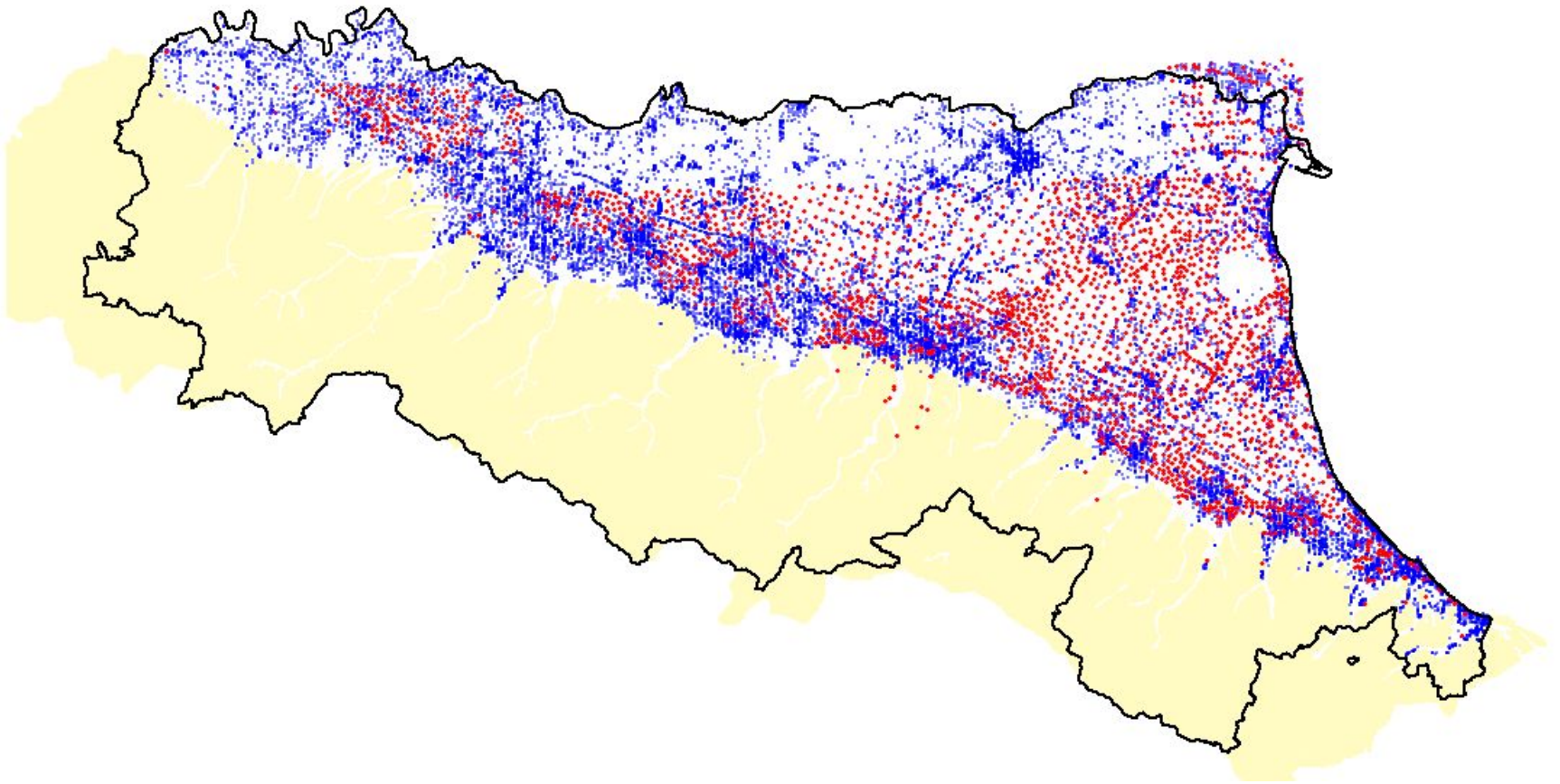
# THE APPROACH TO SUBSIDENCE PROBLEM IN EMILIA-ROMAGNA

- Previous subsidence studies indicate that groundwater withdrawal comes up as one of major responsible for subsidence in the E-R alluvial plain
- By now a) the mathematical modelling and b) subsurface monitoring by *settlement gages* are considered the successful instruments for subsidence understanding
- The definition of a subsurface geologic architecture (bodies geometry, lithology, geotechnical proprieties, etc.) is believed essential to approach to subsidence modelling and for a correct planning of the groundwater management

# THE METHOD

# COLLECTION OF SUBSURFACE GEOLOGICAL DATA:
## The geognostic data-base of Geological Survey in GIS environment

The data base include:
50.000 subsurface stratigraphy from several archives
200 continuous cores and 2000 cone penetration tests CPTU curried out by RER



- subsurface stratigraphy collected from public and private archives
- continuous cores and cone penetration tests of new execution

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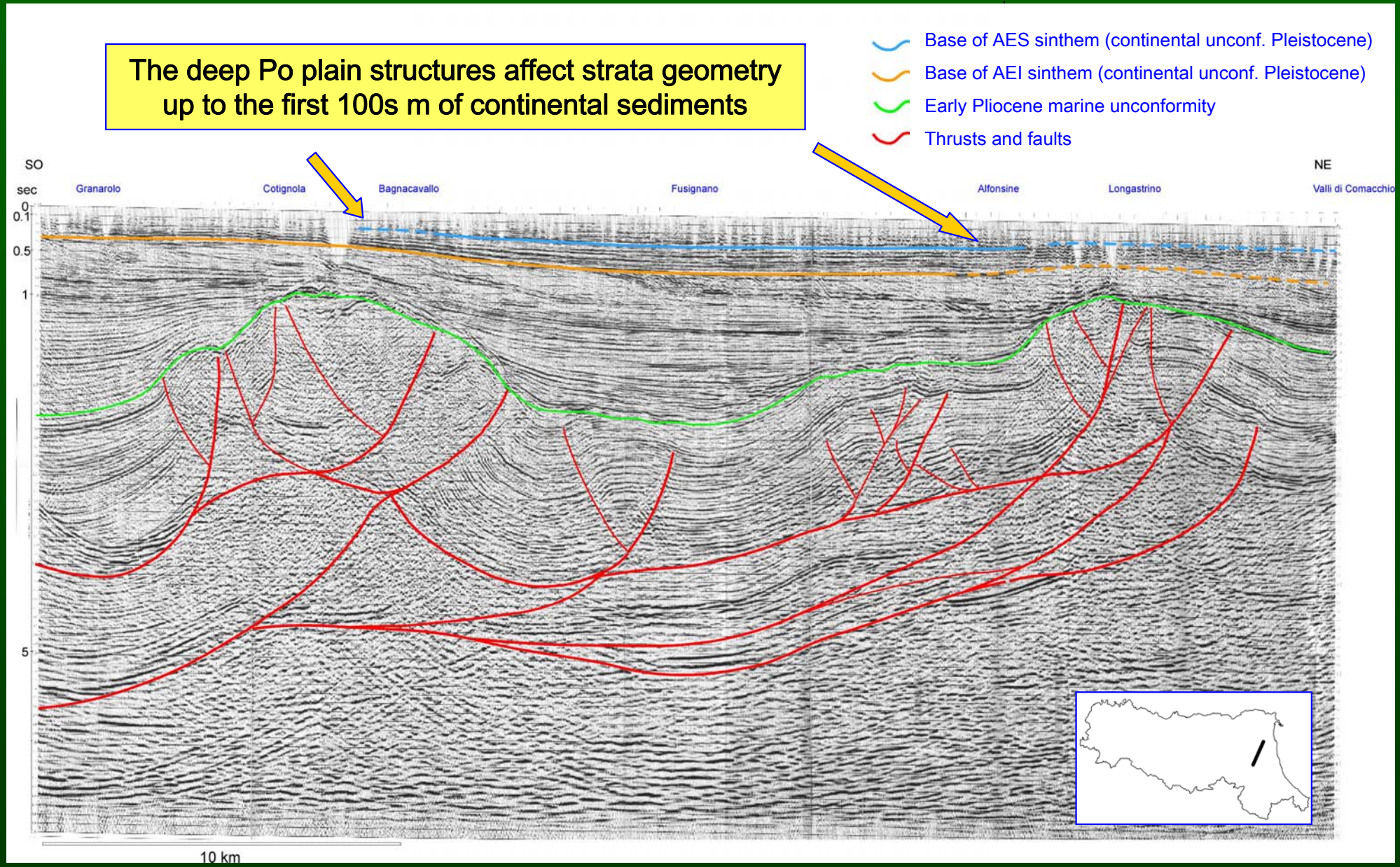
# STRUCTURAL – STRATIGRAPHIC FRAMEWORK AT BASIN SCALE:
## the seismic analysis *(ENI-AGIP data set)*

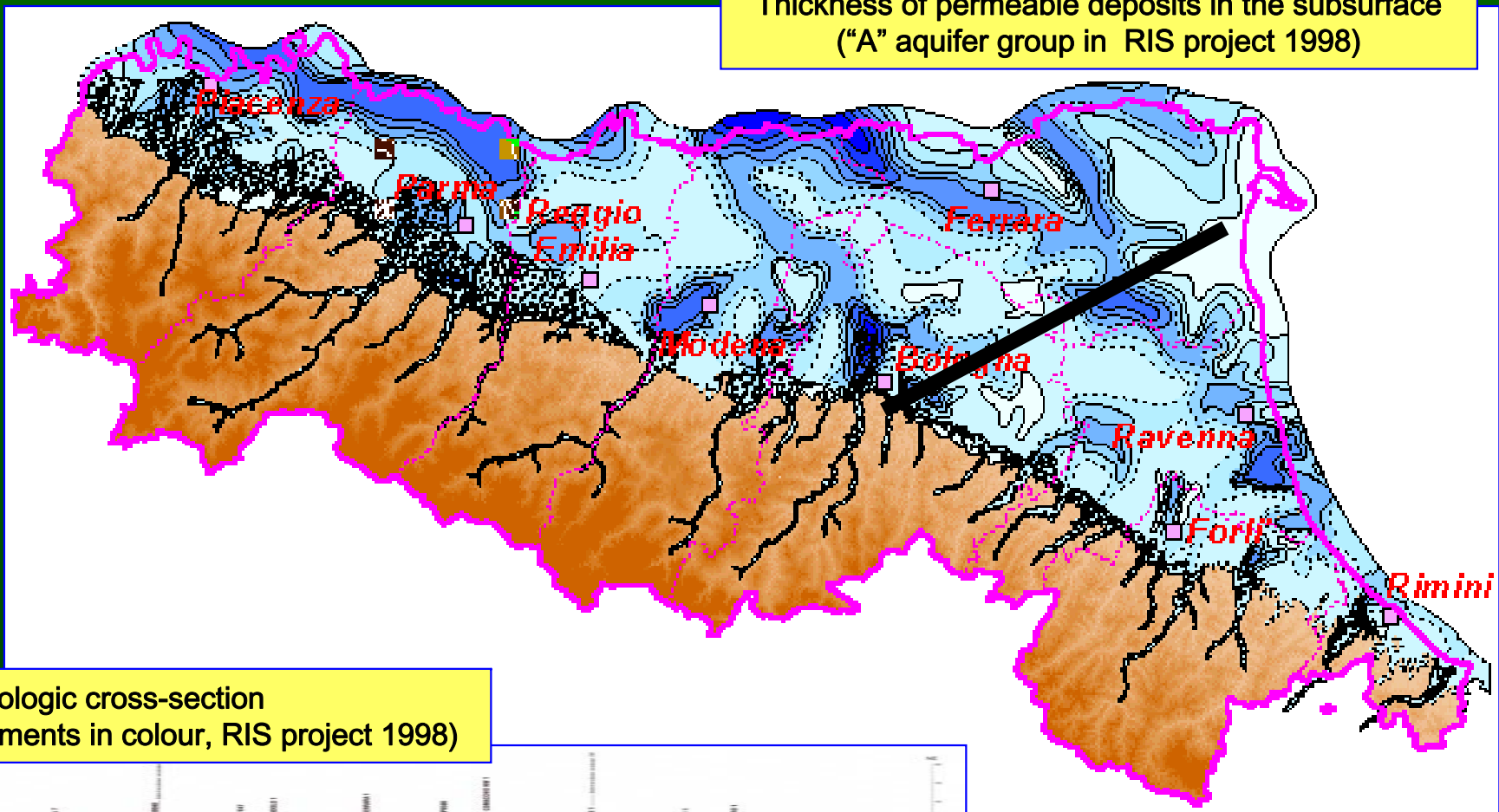
The deep Po plain structures affect strata geometry up to the first 100s m of continental sediments



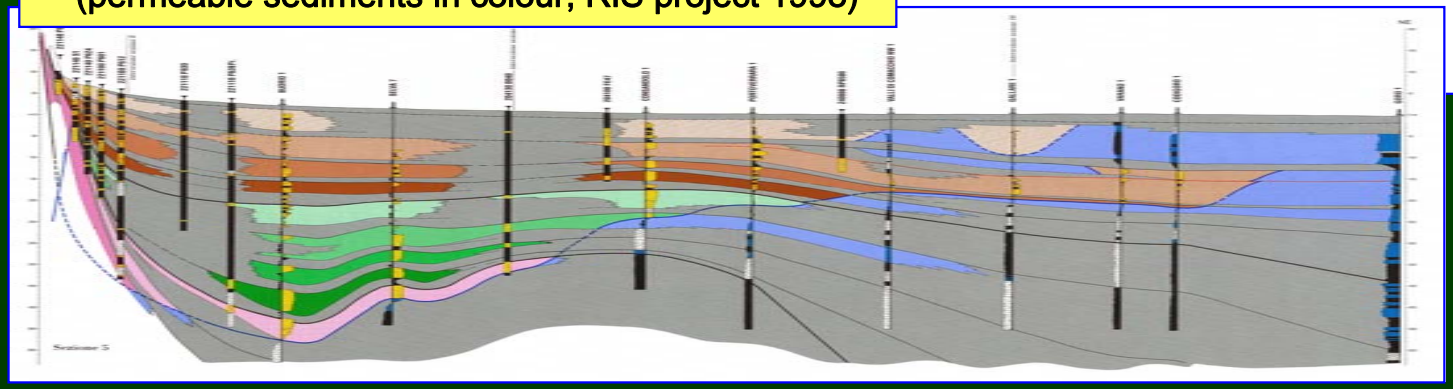
# GEOLOGICAL MODEL AT A BASIN SCALE AND DATA REPORTING:

## Reconstruction of geologic cross-sections and strata geometry

Thickness of permeable deposits in the subsurface
("A" aquifer group in RIS project 1998)




Geologic cross-section
(permeable sediments in colour, RIS project 1998)



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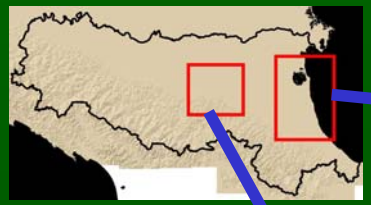
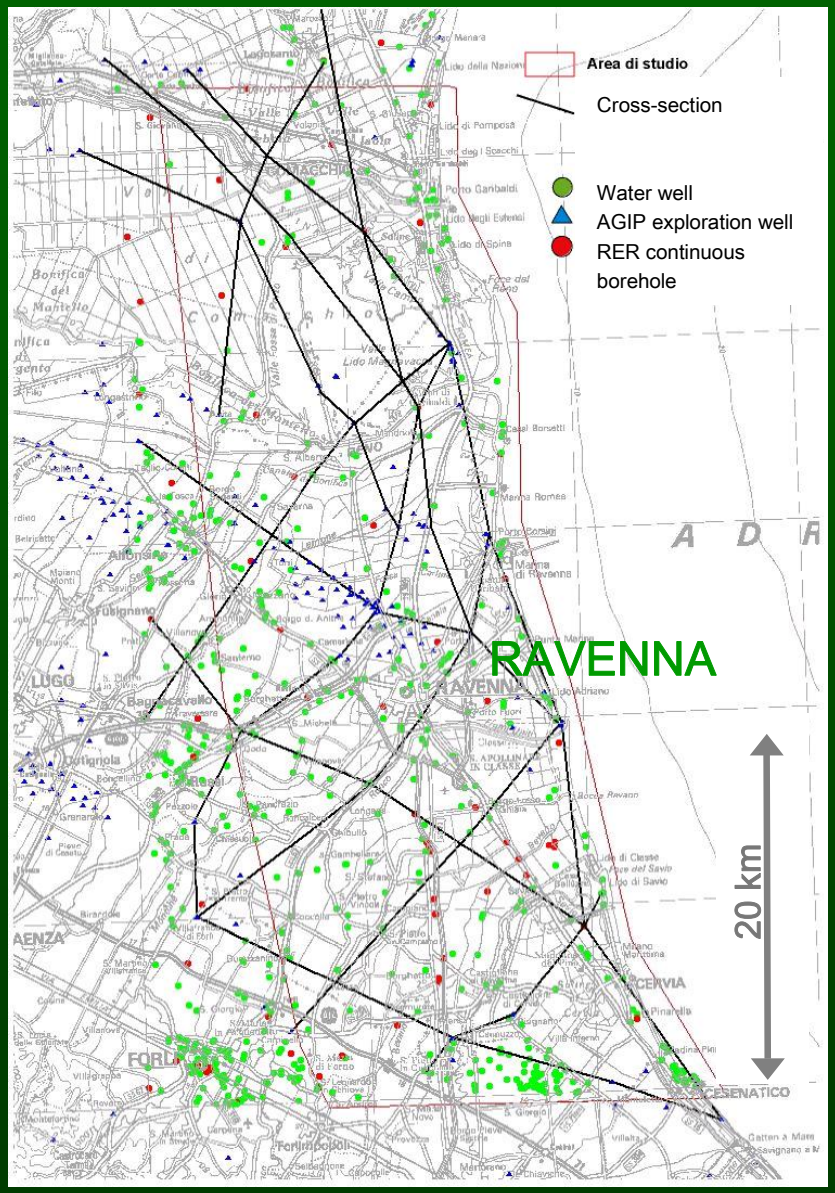
# FROM BASIN TO LOCAL SCALE:

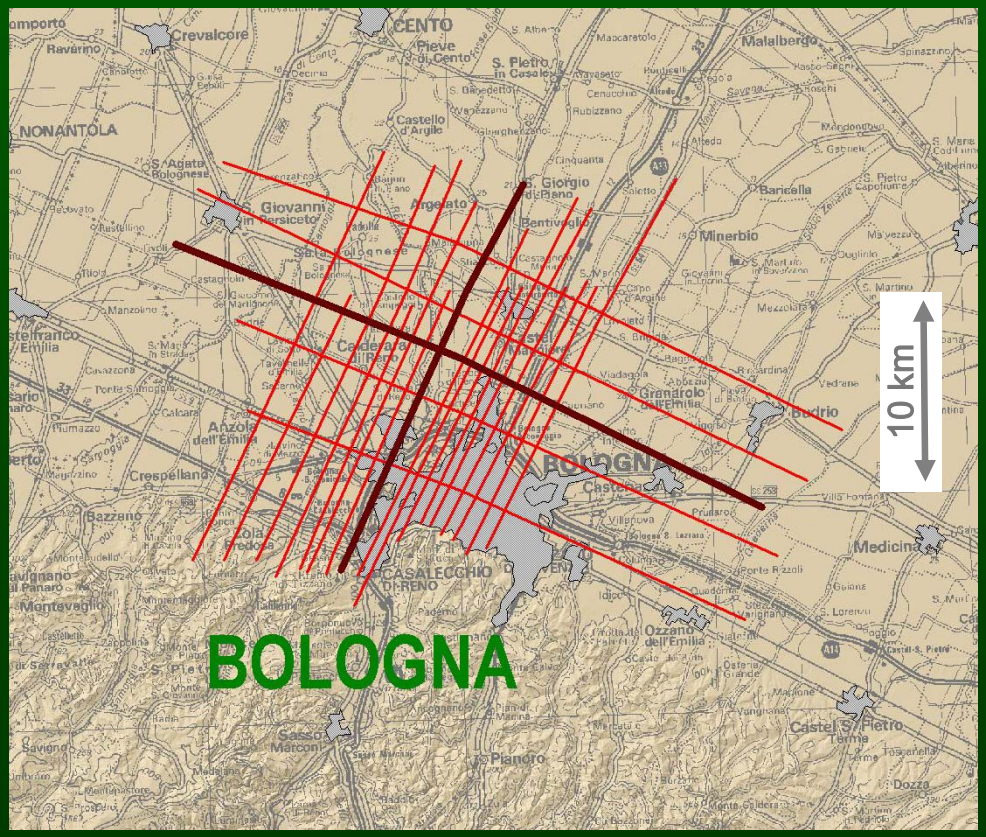
## Grids of detailed geologic cross-sections 100s m to few km spaced



Ravenna coastal plain




Bologna alluvial plain

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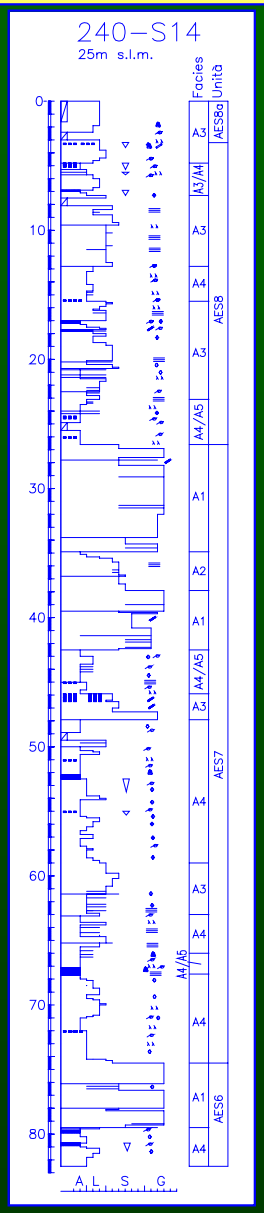
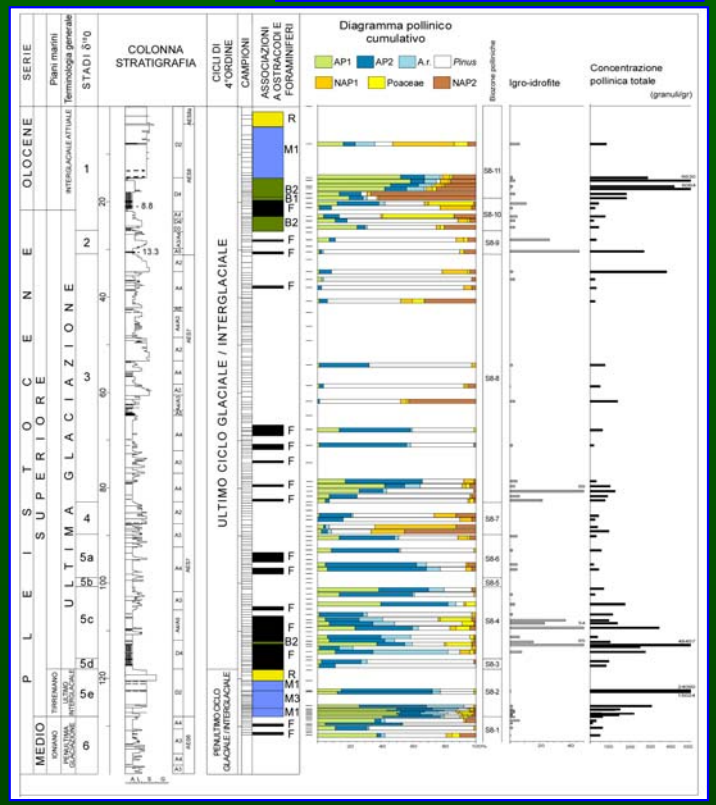
# DRILLING CONTINUOUS BOREHOLES (50-200m depth): Core stratigraphy, *in situ* and laboratory analyses

**Detailed core stratigraphy**



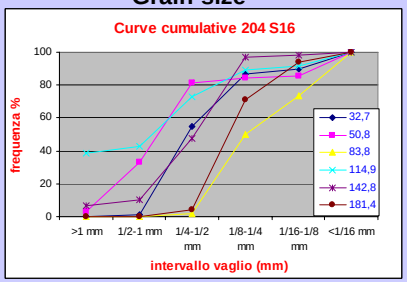

**Biostratigraphy (microfossils, pollen, …)**



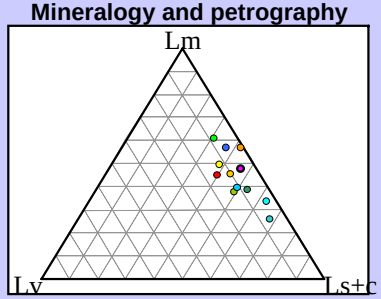

**In situ sampling and investigation**

| | TEST AND SAMPLE | MEASURED PARAMETER |
|---|---|---|
| SAND AND GRAVEL (AQUIFER) | Lefranc test | hydraulic conductivity |
| | water sample | Ph, electric conductivity, geochemistry, isotopes |
| FINES (AQUITARD) | Pocket Penetrometer and Tor Vane | Cohesion<br>Shear resistance |
| | geo-technique sample | grain-size,<br>hydraulic conductivity,<br>compressibility coefficient |
| | organic matter sample | $^{14}C$ radiocarbon age |

**Grain-size**




**Mineralogy and petrography**




**Sand sample analysis**

**In situ facies analysis**

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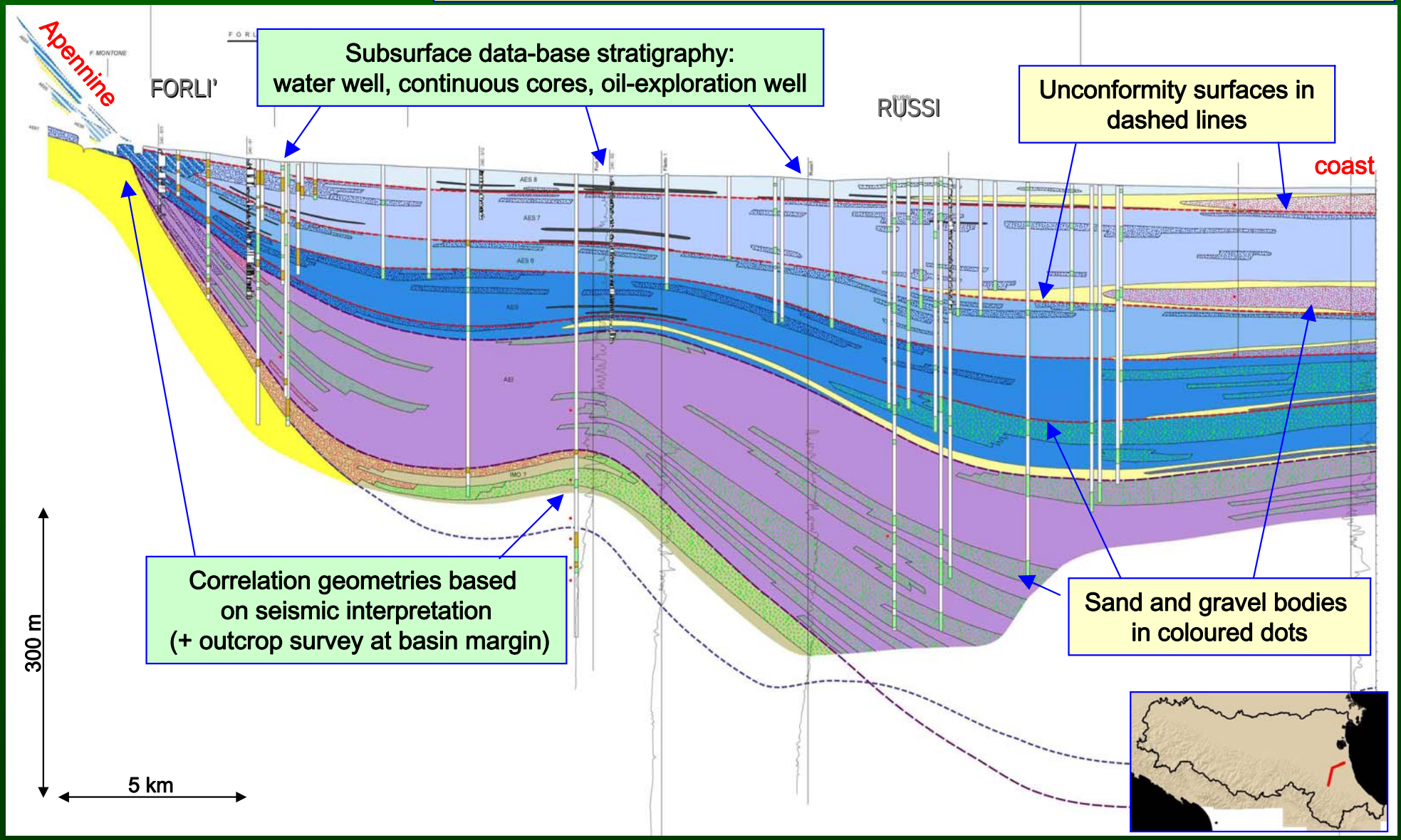
# DATA INTEGRATION AT SEVERAL SCALE:
## The geologic and stratigraphic model of the investigated area

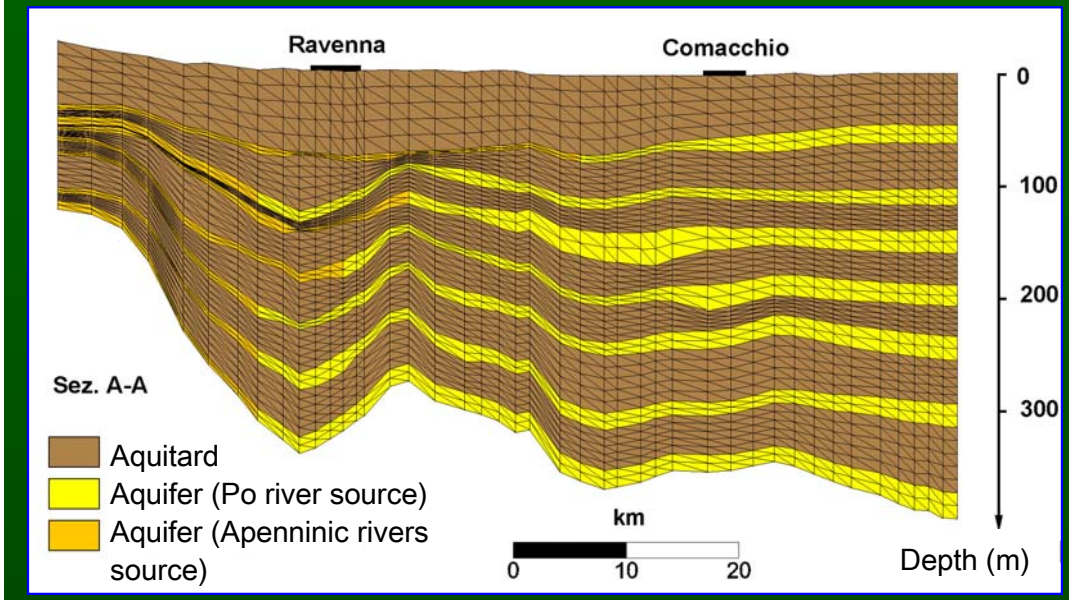
Detailed cross-section from the Apenninic margin to the Adriatic coast



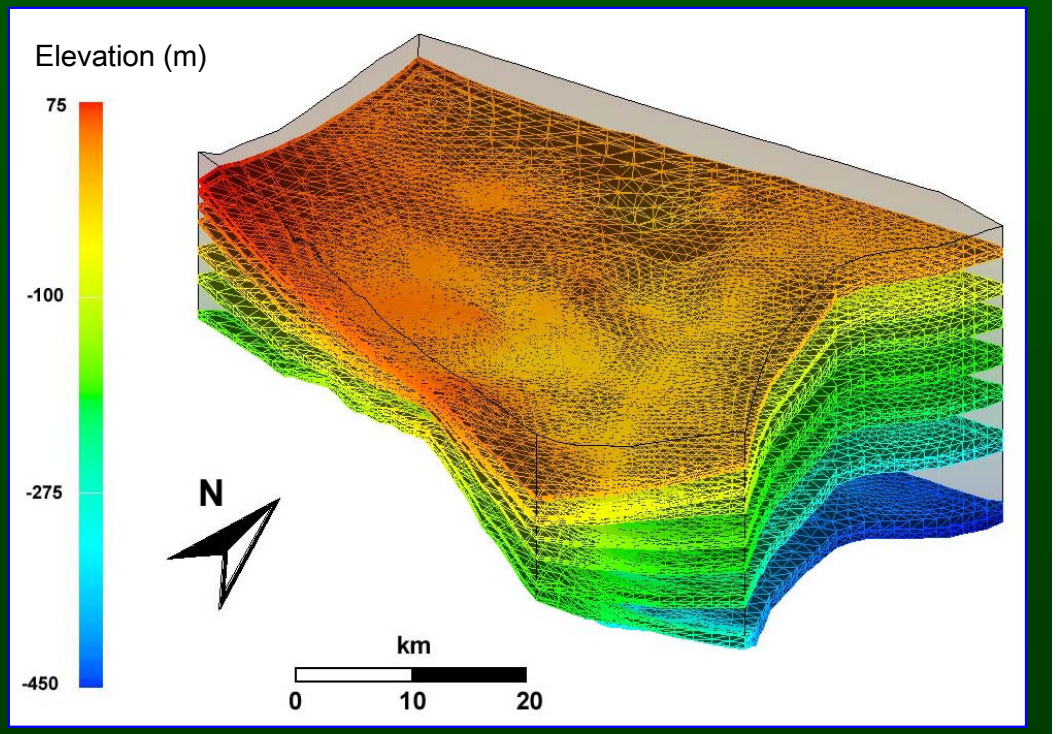
# DATA SELECTION FOR SUBSIDENCE MODELLING AND CONVERSION IN MATHEMATICAL FORMAT

*Mathematic elaboration by Med Ingegneria Srl*

## simplified cross-section




## 3D aquifers geometry




The stratigraphic data are now available for the mathematic model together with water extractions, mechanical parameters, water flux estimations, …..

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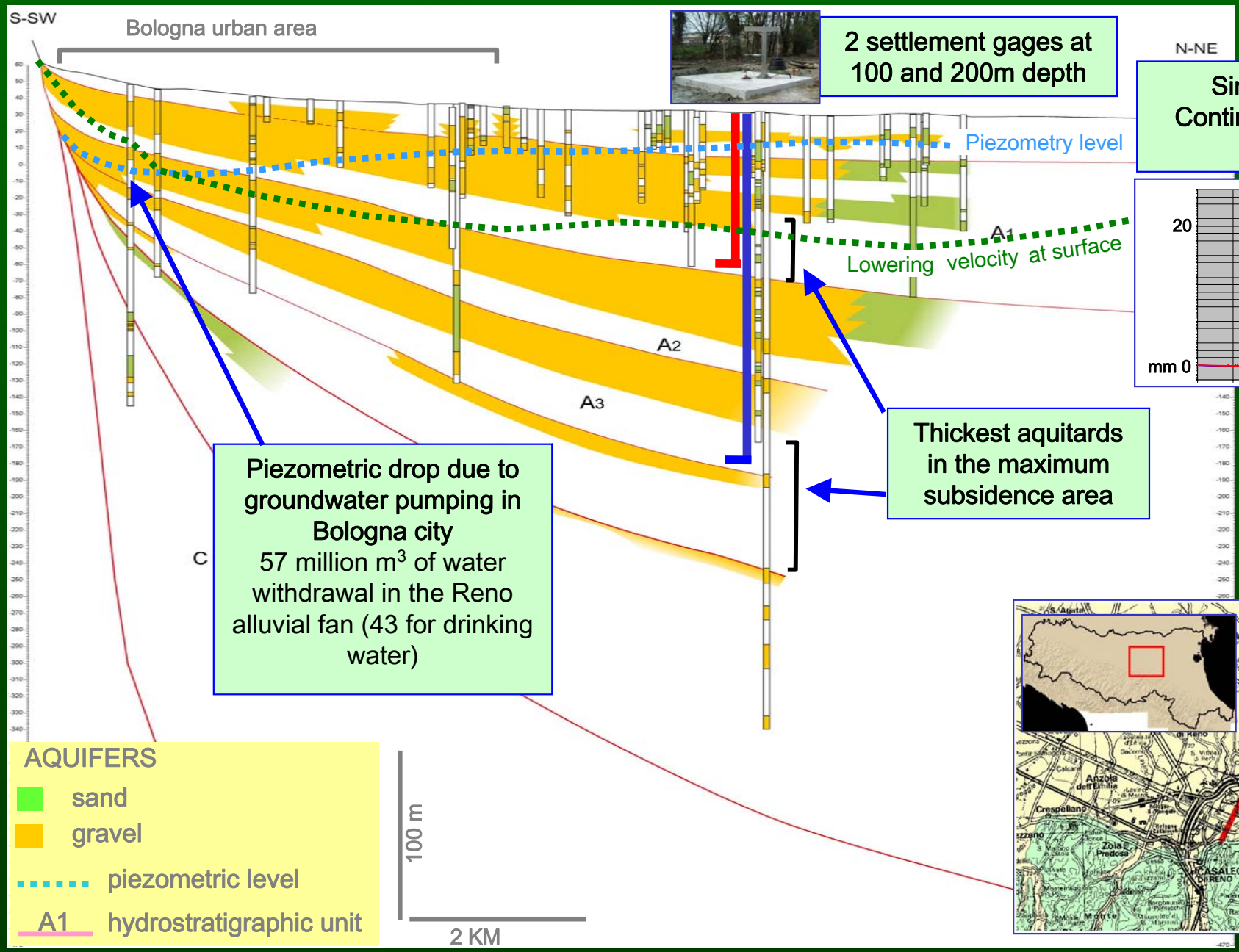
# THE EXAMPLES OF METHOD APPLICATION

# BOLOGNA ALLUVIAL PLAIN: reconstruction of the hydrostratigraphic framework and location of settlement gages for subsidence monitoring

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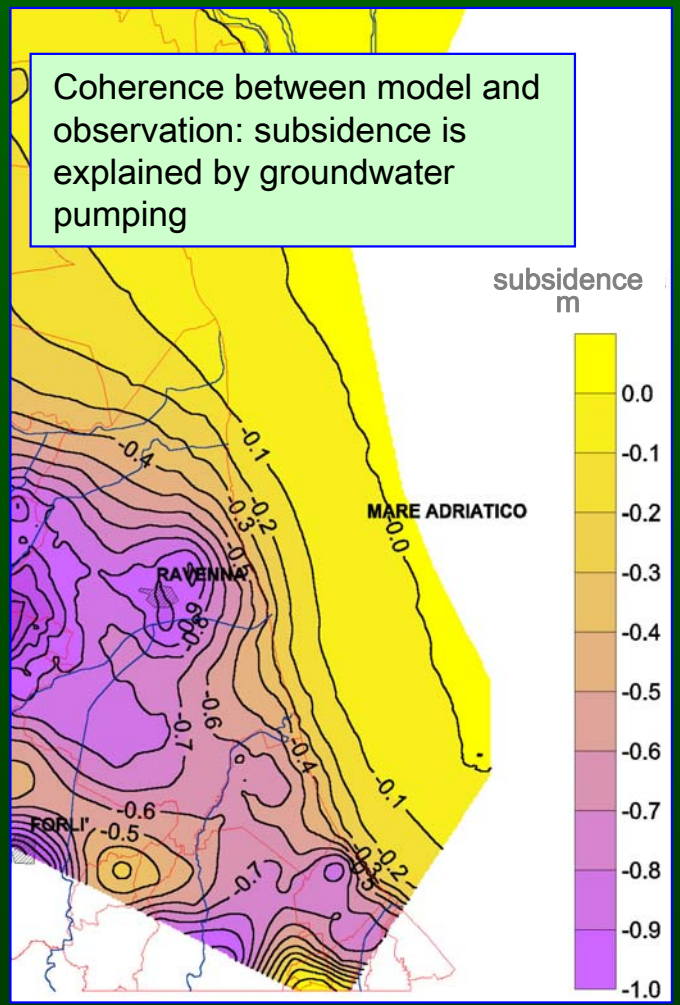
# RAVENNA COAST (*data from final report ENI AGIP–ARPA ER*): Mathematical simulations for historical reconstructions and future scenarios

Subsidence simulation for 1946-2001

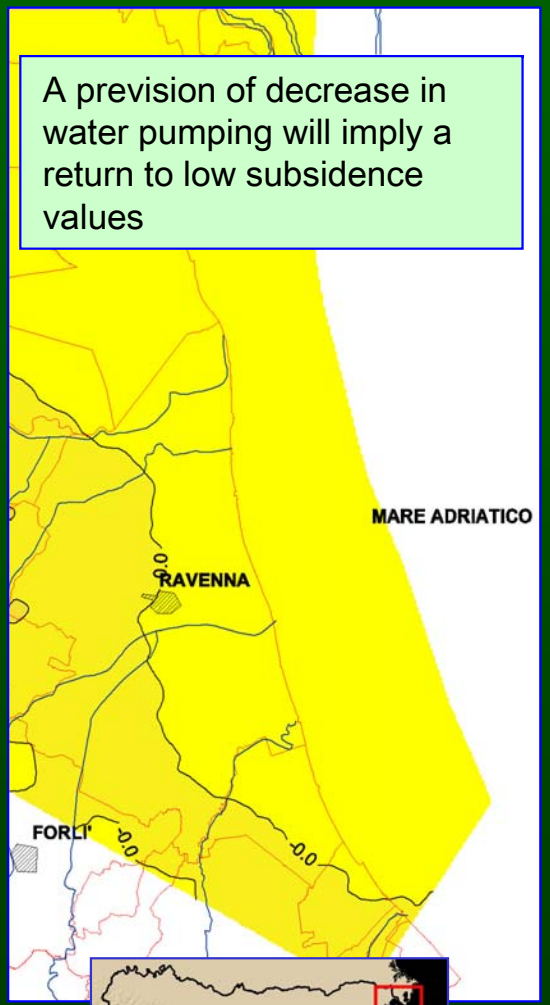
Subsidence prevision for 2001-2016

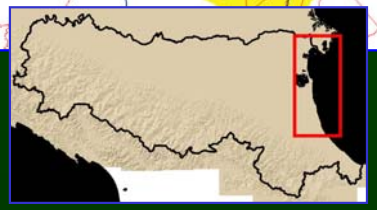
Discrepancy between model and observations

Coherence between model and observation: subsidence is explained by groundwater pumping

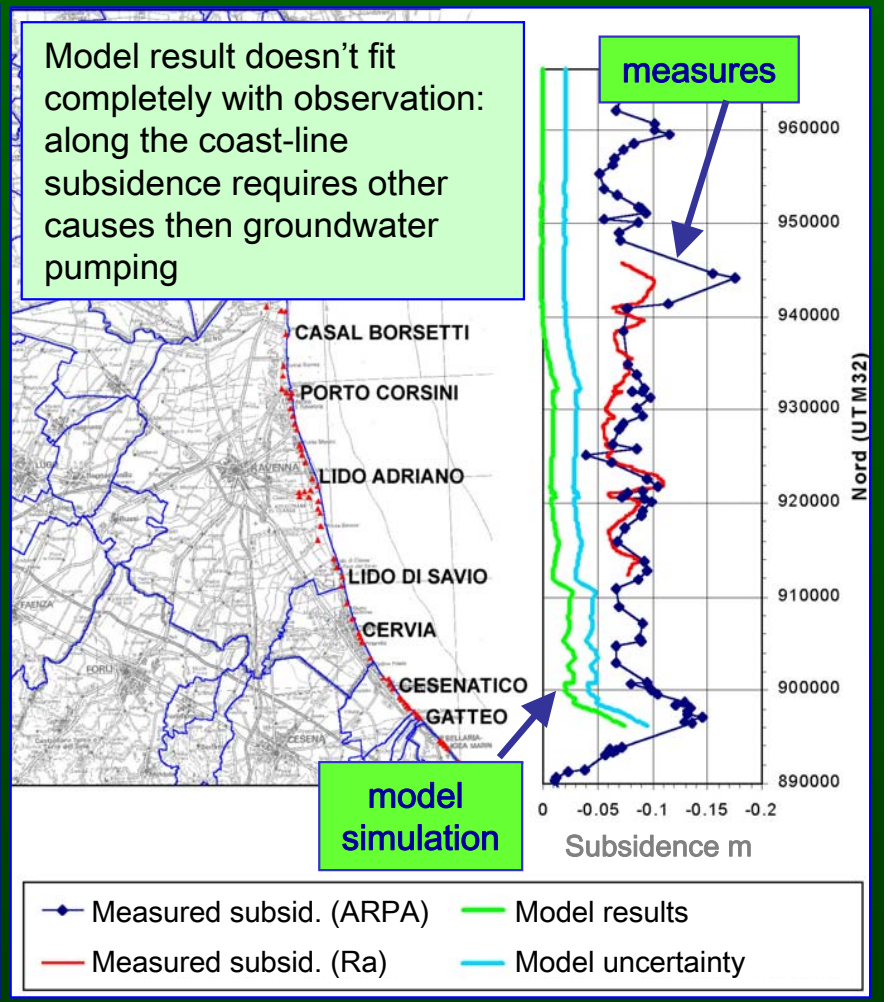



A prevision of decrease in water pumping will imply a return to low subsidence values



Model result doesn't fit completely with observation: along the coast-line subsidence requires other causes then groundwater pumping

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# CONCLUSIONS

- In these first experiences of the last few years E-R Geological Survey developed a methodology to define geologic architecture of the subsurface to support analysis of Po Plain subsidence
- Such a geological framework can be successfully integrated and used in mathematical modelling
- It is a valid support to design the 3D monitoring system by surface measurements and subsurface settlement gages
- In the very next future geologic & mathematic modelling will be the needful support for the sustainable management of groundwater resource