3D Geological modeling of the coastal area in Emilia-Romagna, Italy

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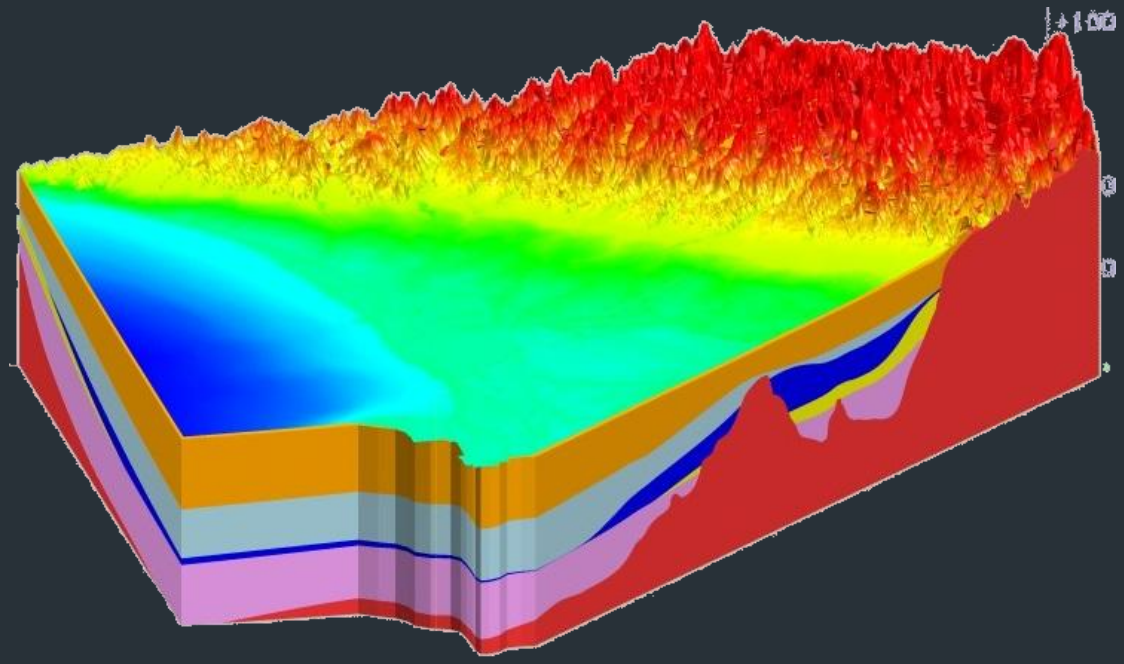

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3D geological modeling of the coastal area of Emilia-Romagna, Italy. Calabrese et al.

servizio geologico sismico e dei suoli

RegioneEmilia-Romagna

CNR Consiglio Nazionale delle Ricerche

ISMAR Istituto di Scienze Marine

The coast of Emilia-Romagna

Features

- 130 km of flat sandy coast
- Alluvial to deltaic/littoral depositional systems
- Thick Holocene trasgressive-regressive sedimentary sequence

Land Use

- Widespread urban area
- Natural environments as dunes, wetlands and lagoons

Problematic aspects

- Coastal erosion
- Sea-flood
- Subsidence
- Salinization of acquifer
- Liquefaction and settlements

Why a 3D modelling?

- To represent the great amount of available territorial information
- To increase the understanding of a complex reality like the geological one
- To provide new tools for specific studies such as hydrogeological, geotechnical, risk analysis etc.

Available data

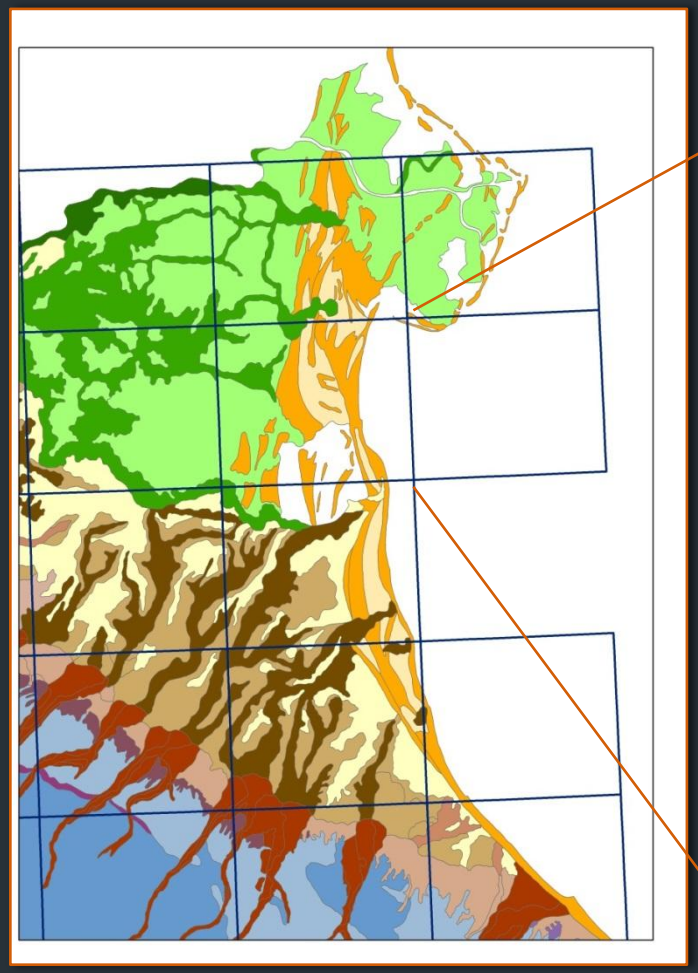
A huge amount of data has been stored in the SGSS-RER Information Systems :

- Geological and thematic maps, geological cross-sections
- Seismic profiles
- High resolution digital terrain models
- Geognostic Data Base

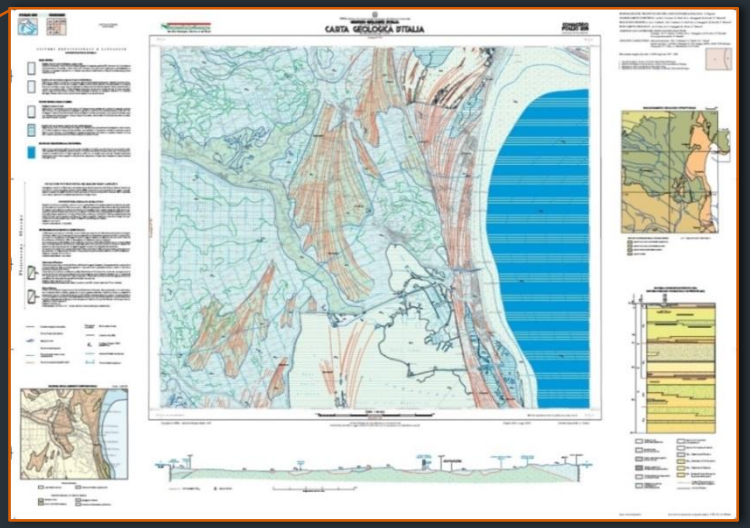
..and a long-standing experience in the study of the geology of this area

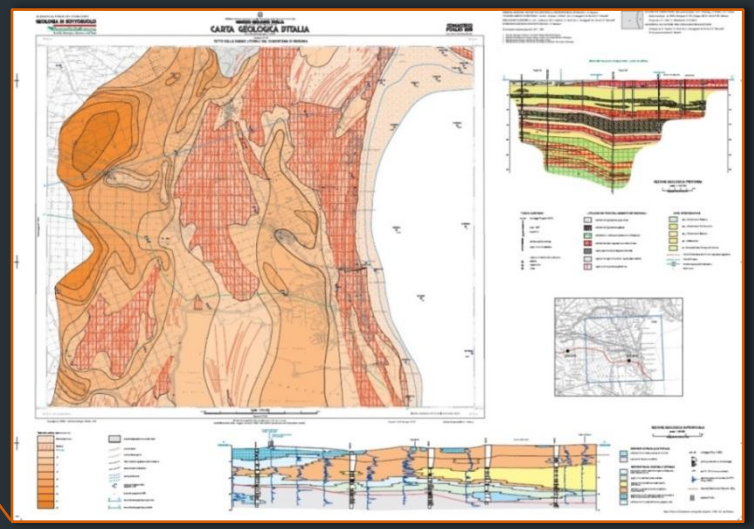
Geological Maps

Geological Maps of national project CARG 1:50000 (1997-present)



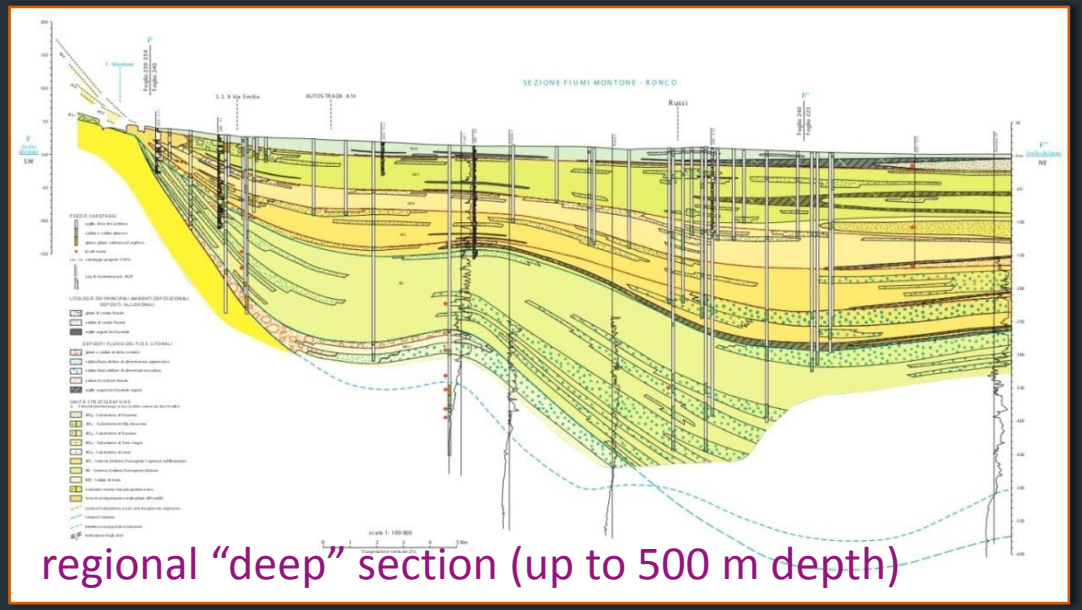
Geological Map of Emilia-Romagna Alluvial Plain 1:250,000 (1999)



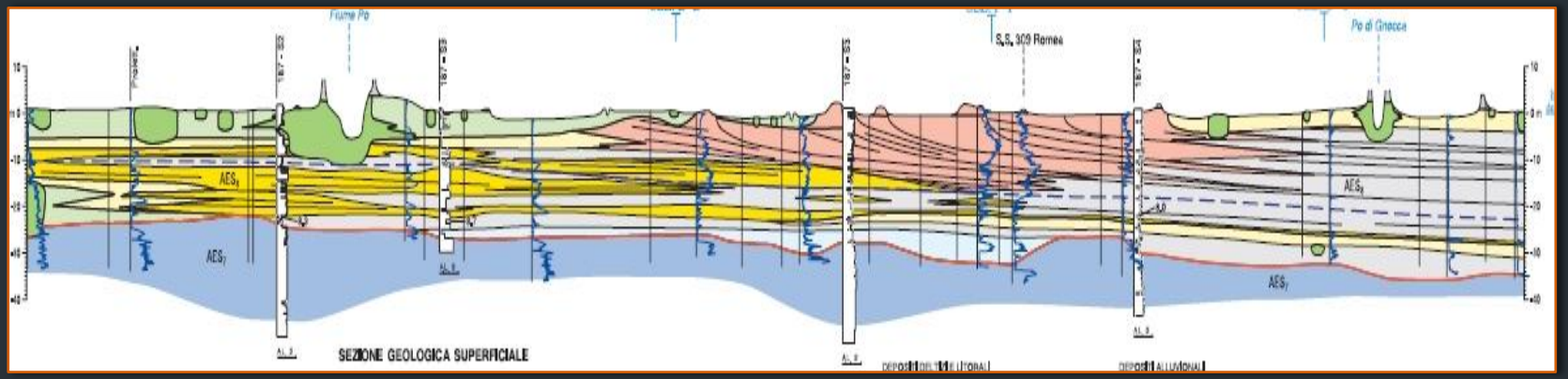


Cross-sections

Geological cross-section trace in the coastal area

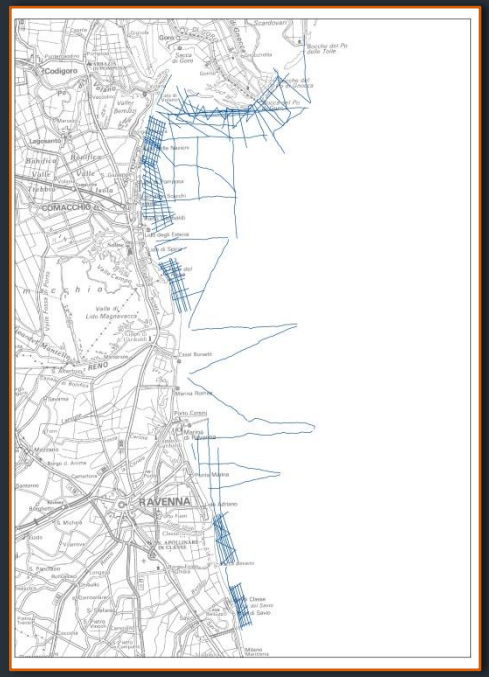


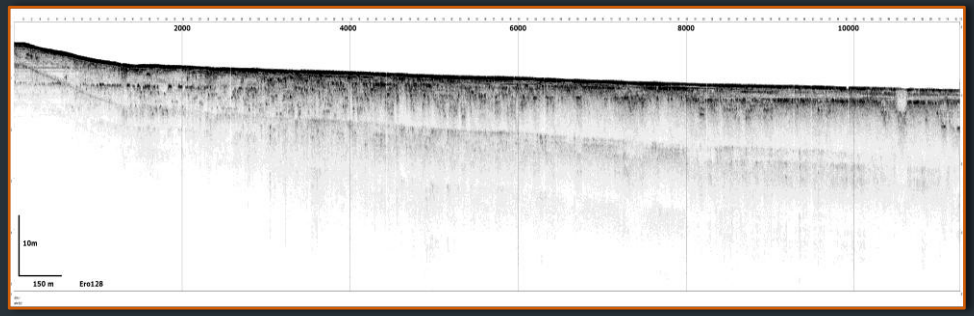
regional “deep” section (up to 500 m depth)

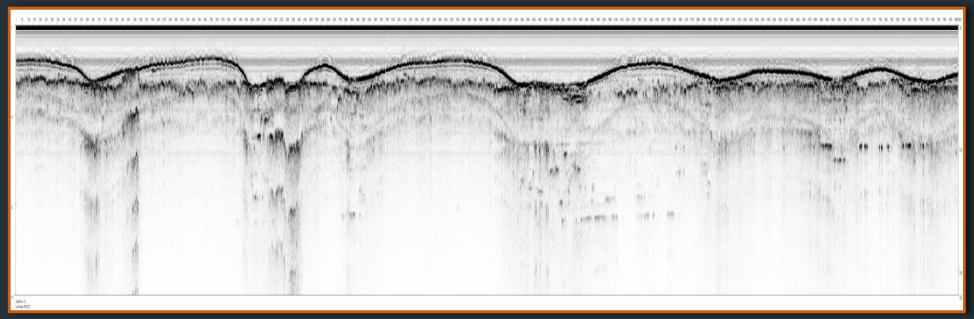


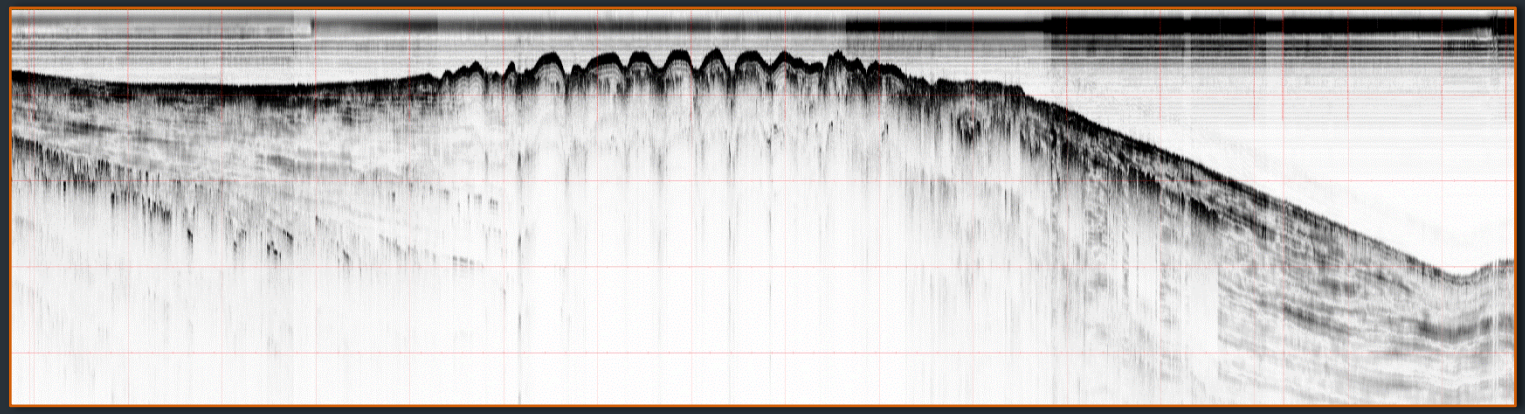
detailed “surficial” section (up to 40 m depth)

Seismic profiles



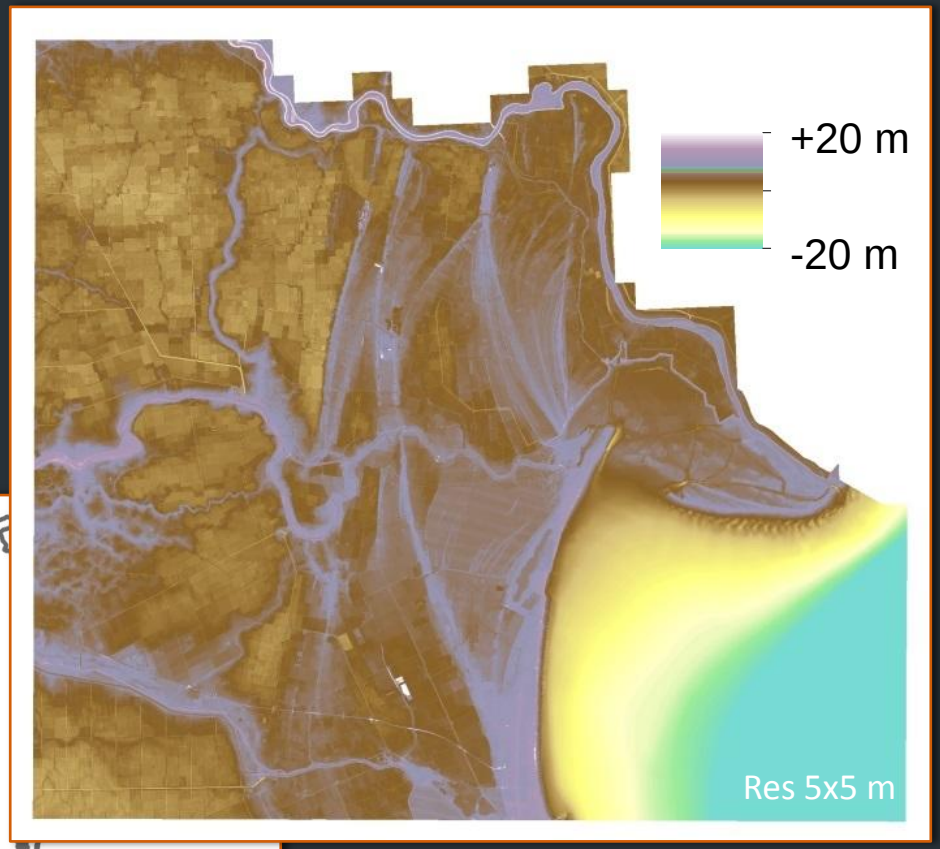


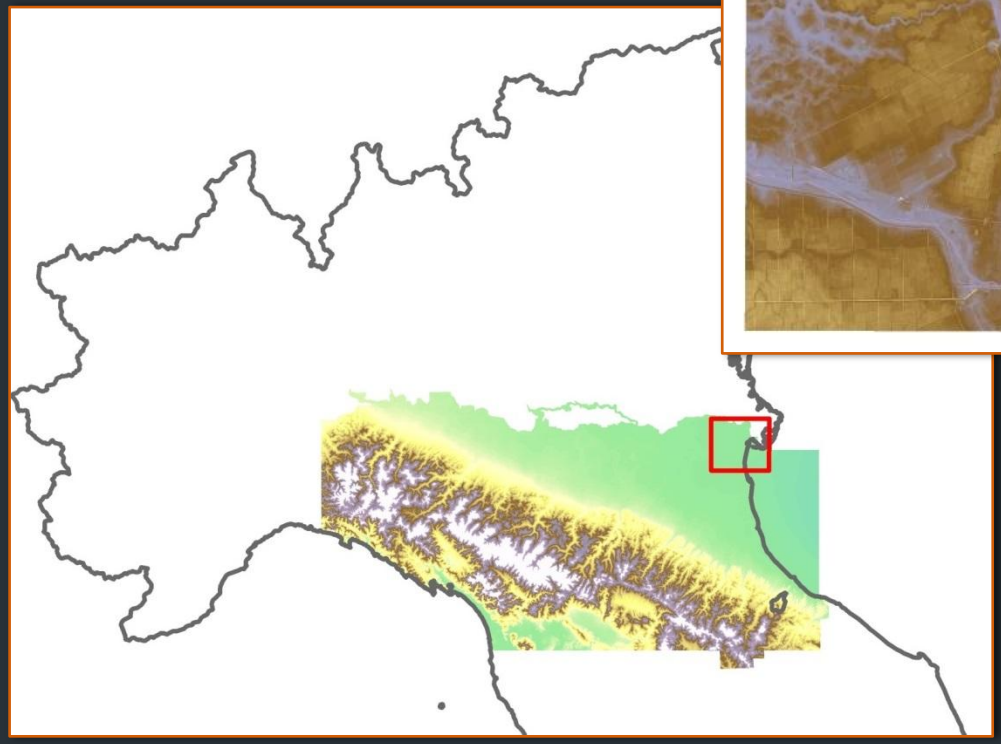




Digital Terrain Models

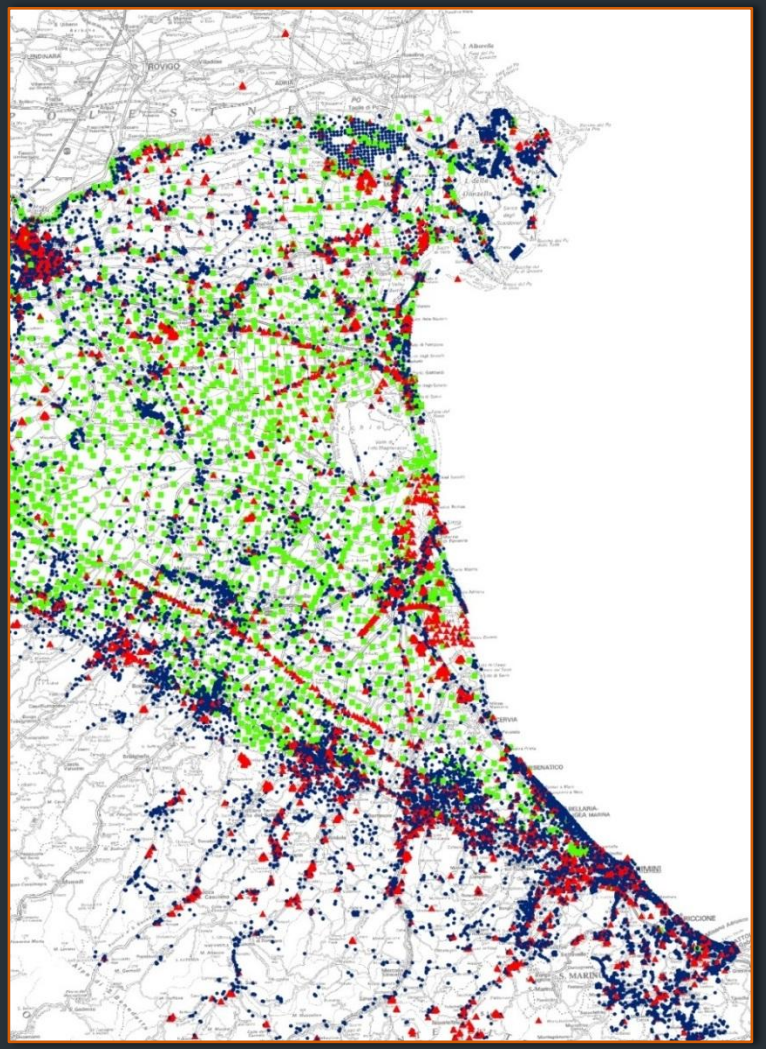
Resolution up to 1x1 m
Surveys from 2004 to 2012





Geognostic Data Base

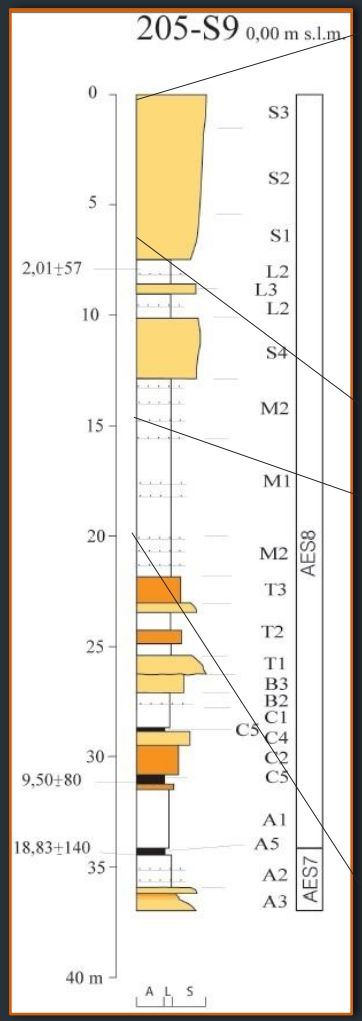
A dense distribution of georeferenced geognostic data provides important information on lithology and physical characteristics of the sedimentary sequence, from a few meters up to hundreds of meters



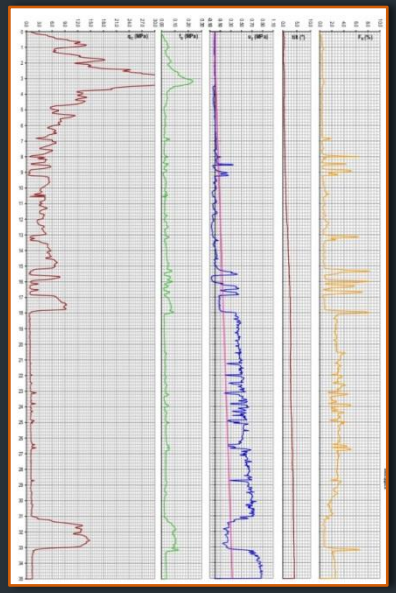
- Corings
- Water Wells
- Piezocone Penetration Tests (CPTU)

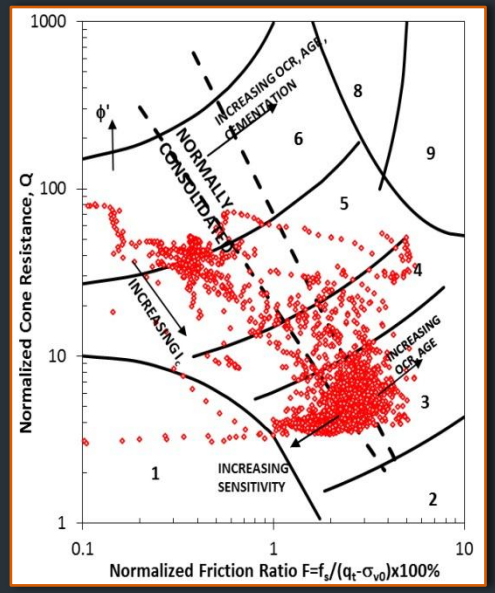
Geognostic Data Base

Corings and facies analysis

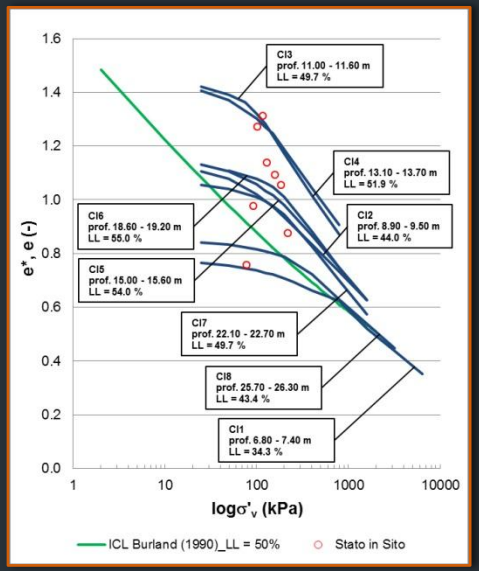


CPTU and numeric elaboration





Samples and laboratory analysis



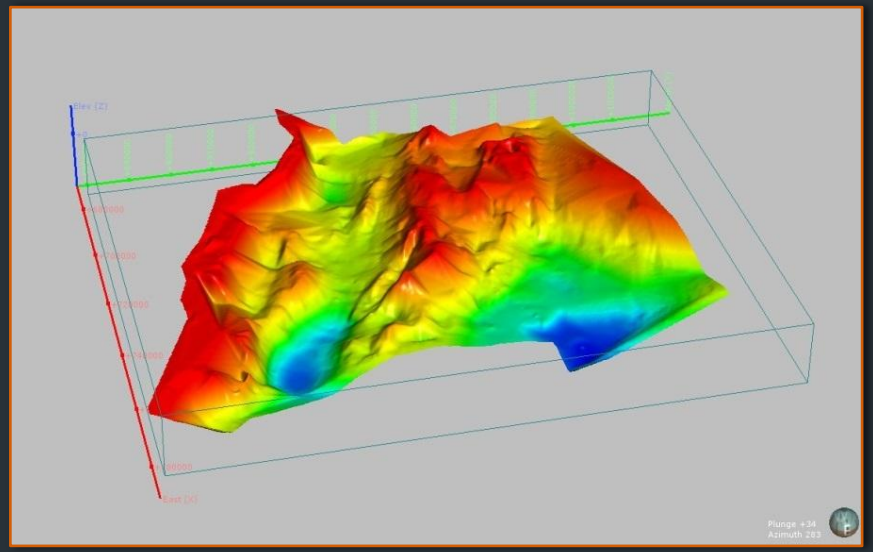
The 3D software

We chose a product with specific functionality, able to respond to our needs. Basic points to our purposes are:

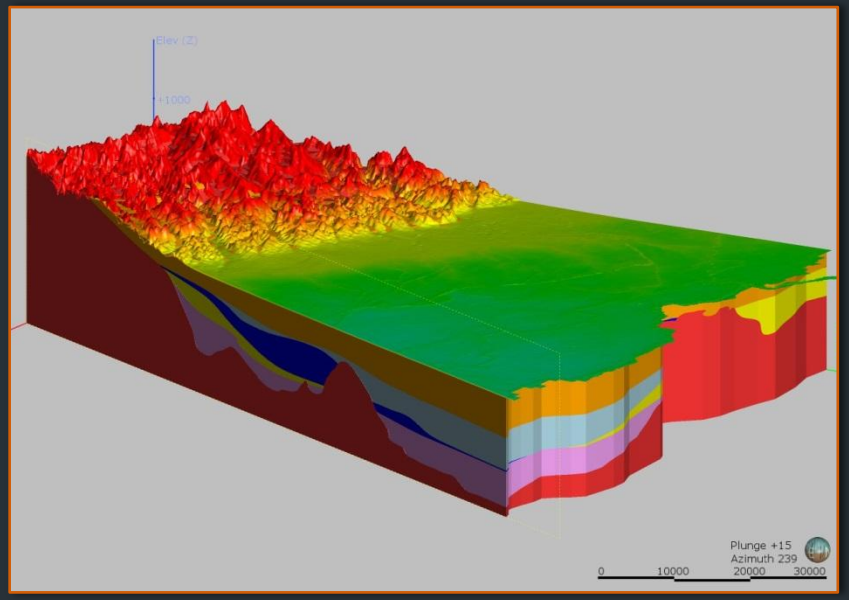
- use and integrate all available data;
- campatibility with our structurated data base;
- compatibility with GIS technology and dataset;
- relevant to reproduce the stratigraphy of the Po Valley;
- ability to check and correct the work manually according to the real experience of geologists;
- versatility in many application fields.

Application fields

Statigraphic analysis of sedimentary successions (regional scale)



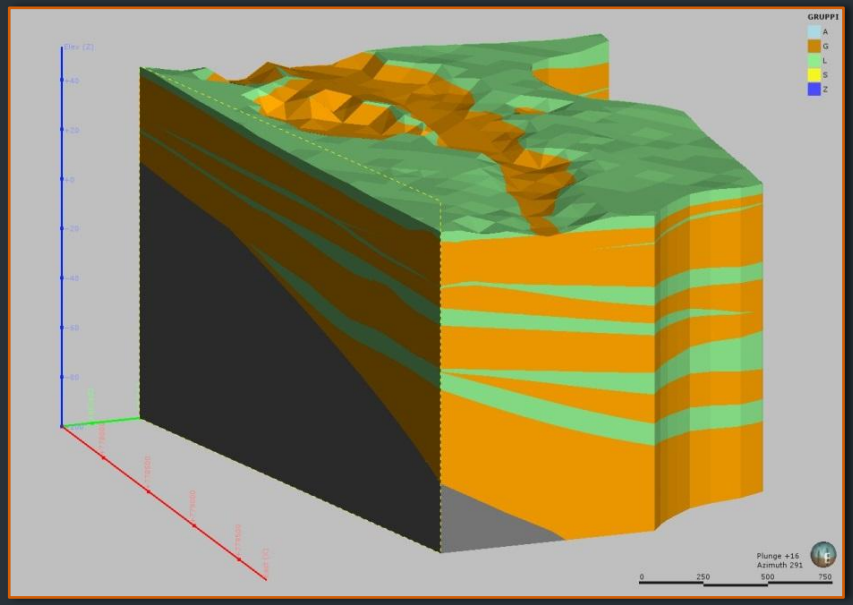
Mapping of stratigraphic surfaces (Top of Pliocene – eastern Po Plain and Appennine margin)
Area: 10000 Kmq
Max depth: 2500 m



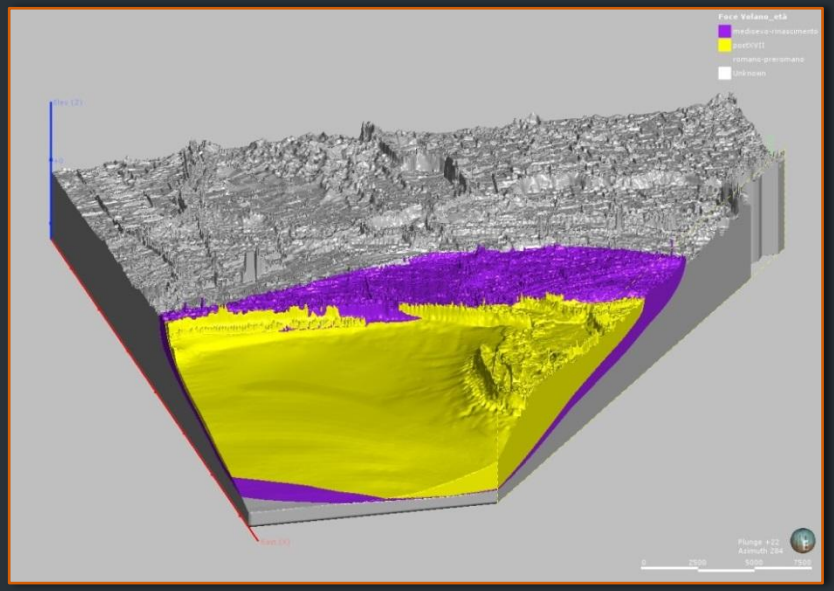
Stratigraphy of the Quaternary succession (eastern Po Plain and Appennine margin)
Area: 25000 Kmq
Max thickness: 3500 m

Application fields

Reconstruction of complex architectures (local scale)



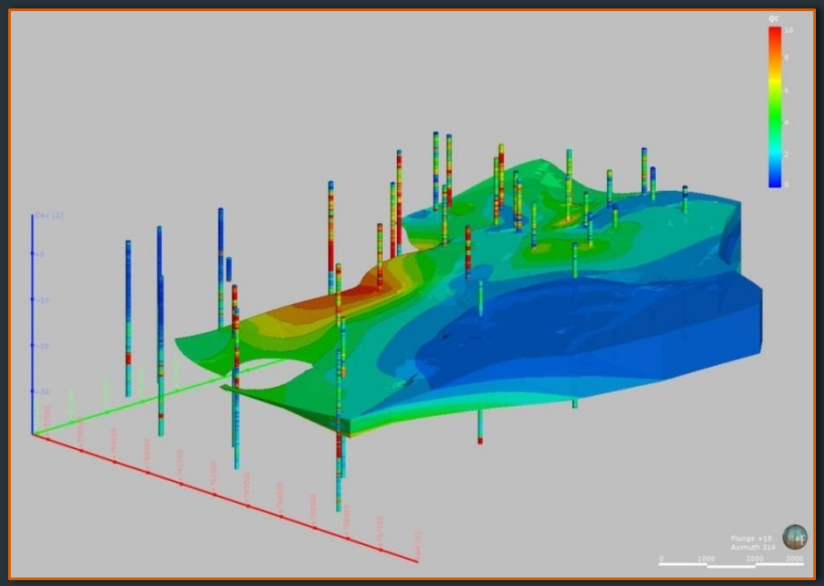
Detailed geometries of aquifers and aquitards (Marecchia alluvial fan – Rimini)
Area: 4.6 Kmq
Max thickness: 150 m



Definition of shape and volume of southern Po delta lobes (Po di Volano and Po di Goro – Ferrara)
Area: 1000 Kmq
Thickness: 40 m

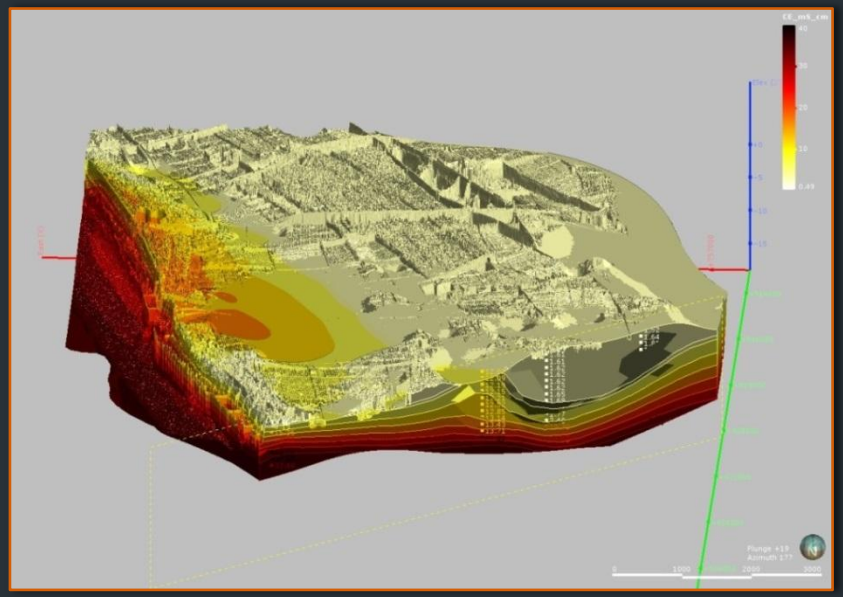
Application fields

Variations of parametric values within geological bodies



Cone penetration resistance (Qc) trend from CPTU within the prodelta wedge (Lido di Classe – Ravenna)
Area: 120 Kmq
Max thickness: 16 m

Variation of the electrical conductivity (EC) within the groundwater of the coastal phreatic aquifer (Lido di Classe - Ravenna)
Area: 120 Kmq
Max thickness: 15 m

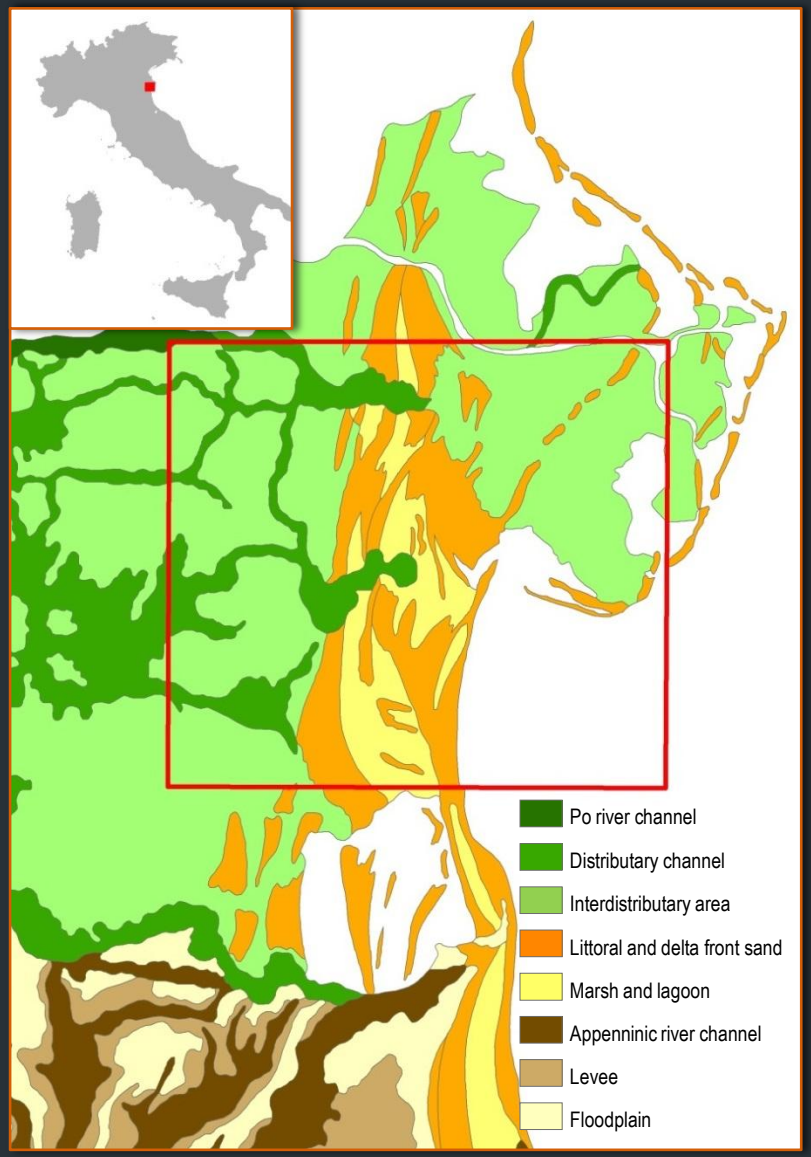


Case study

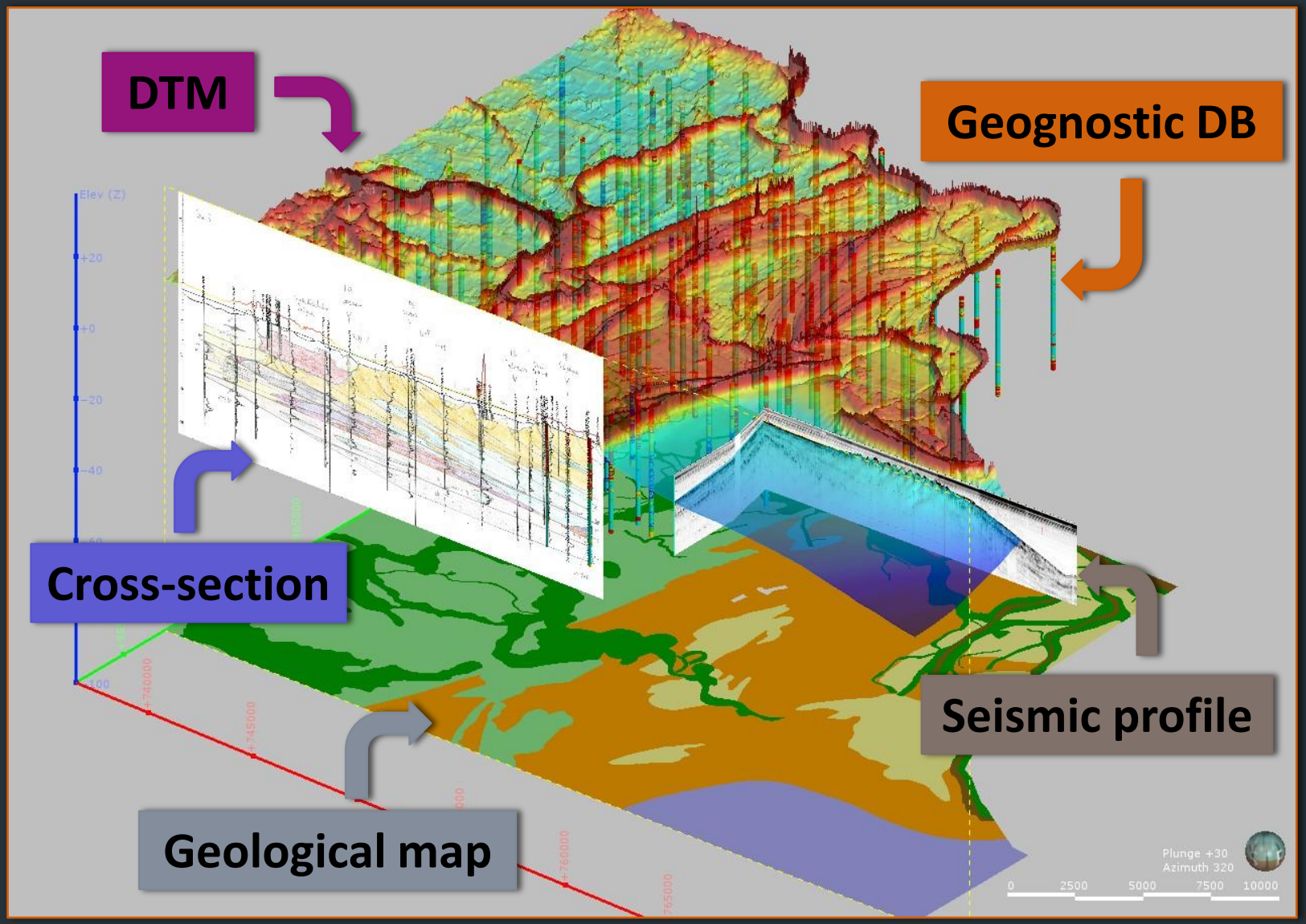
3D model of the Holocene succession in the Southern Po Delta

OVERVIEW

- This sector is characterized by a thick (up to 35 m) Holocene T-R sequence with continental to marine then to deltaic deposits.
- The upper part of the sequence records the progradation of the Po di Volano and Po di Goro delta lobes.
- Po di Volano was active from the Roman period to the XVI century; Po di Goro has grown since the XVII century to the present.



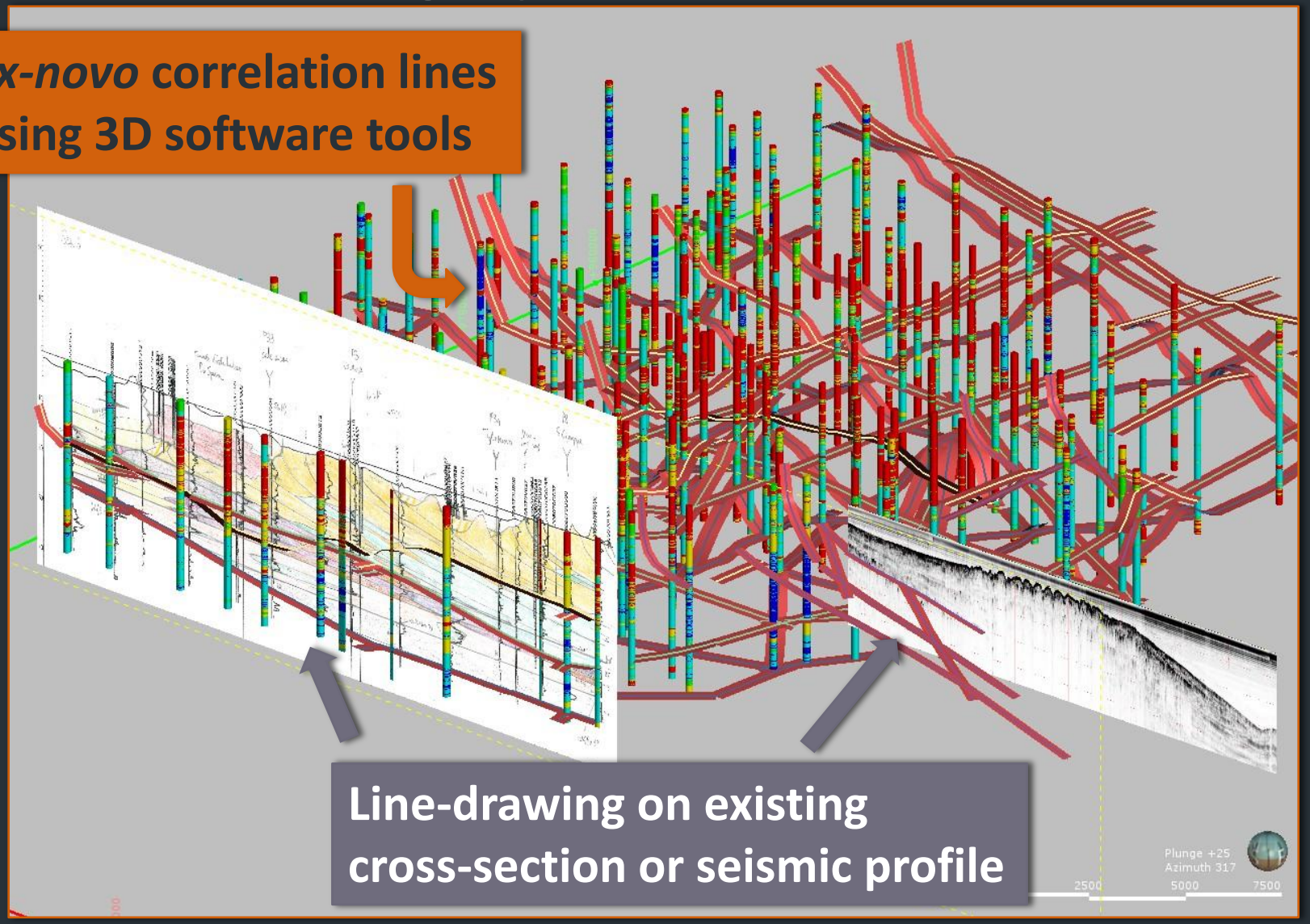
Available data



Model creation 1

Stratigraphic correlations

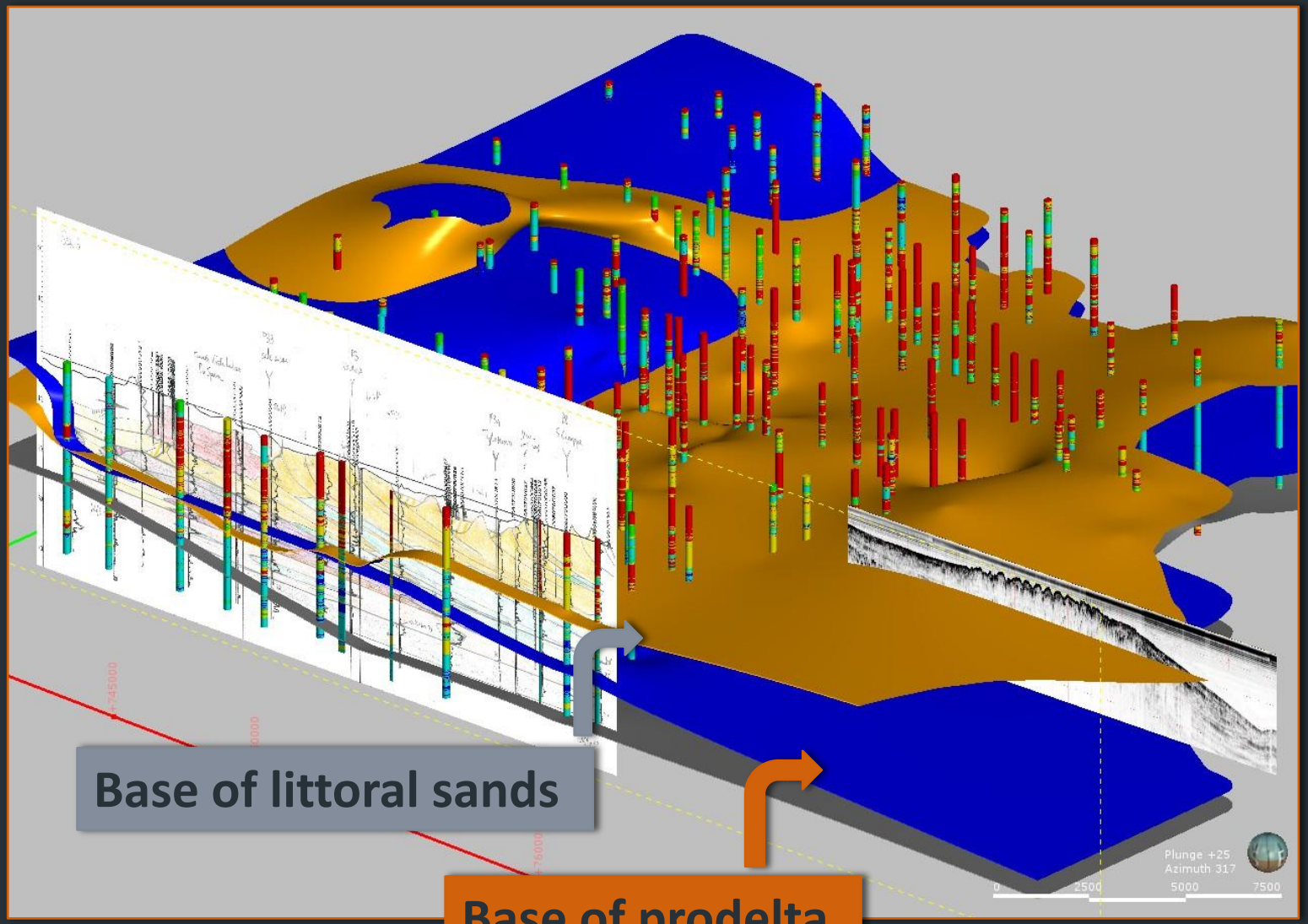
***Ex-novo* correlation lines using 3D software tools**



Line-drawing on existing cross-section or seismic profile

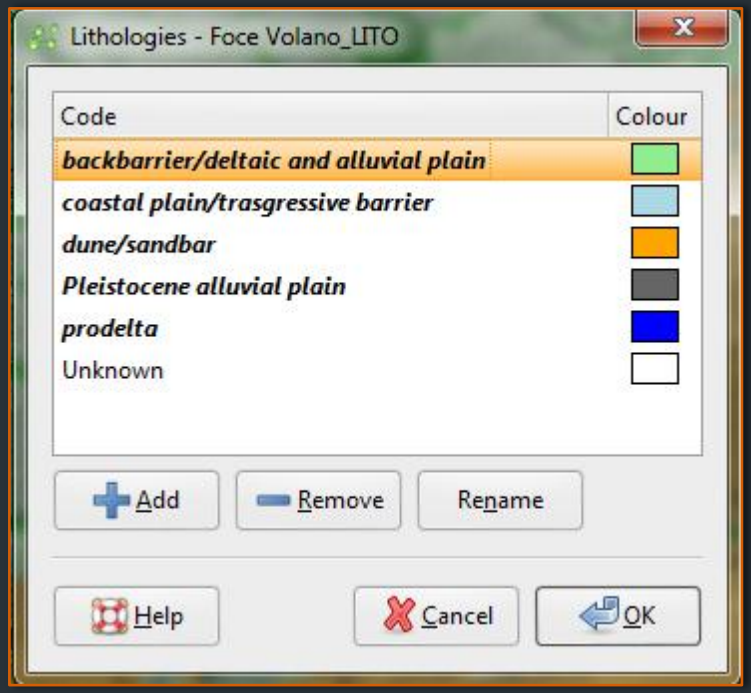
Model creation 2

Stratigraphic surfaces



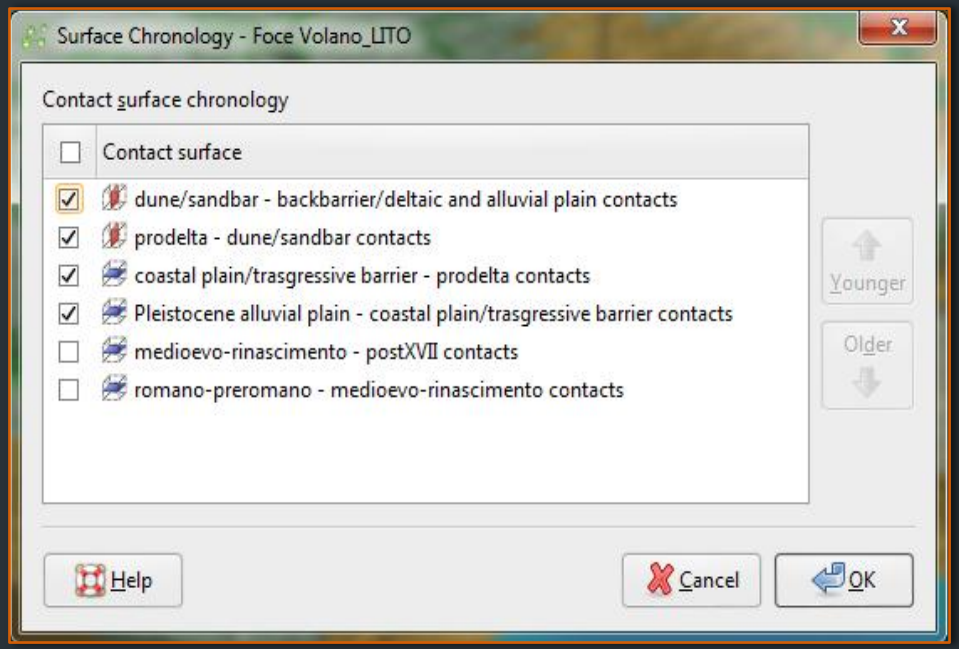
Model creation 3

Statigraphic Scheme



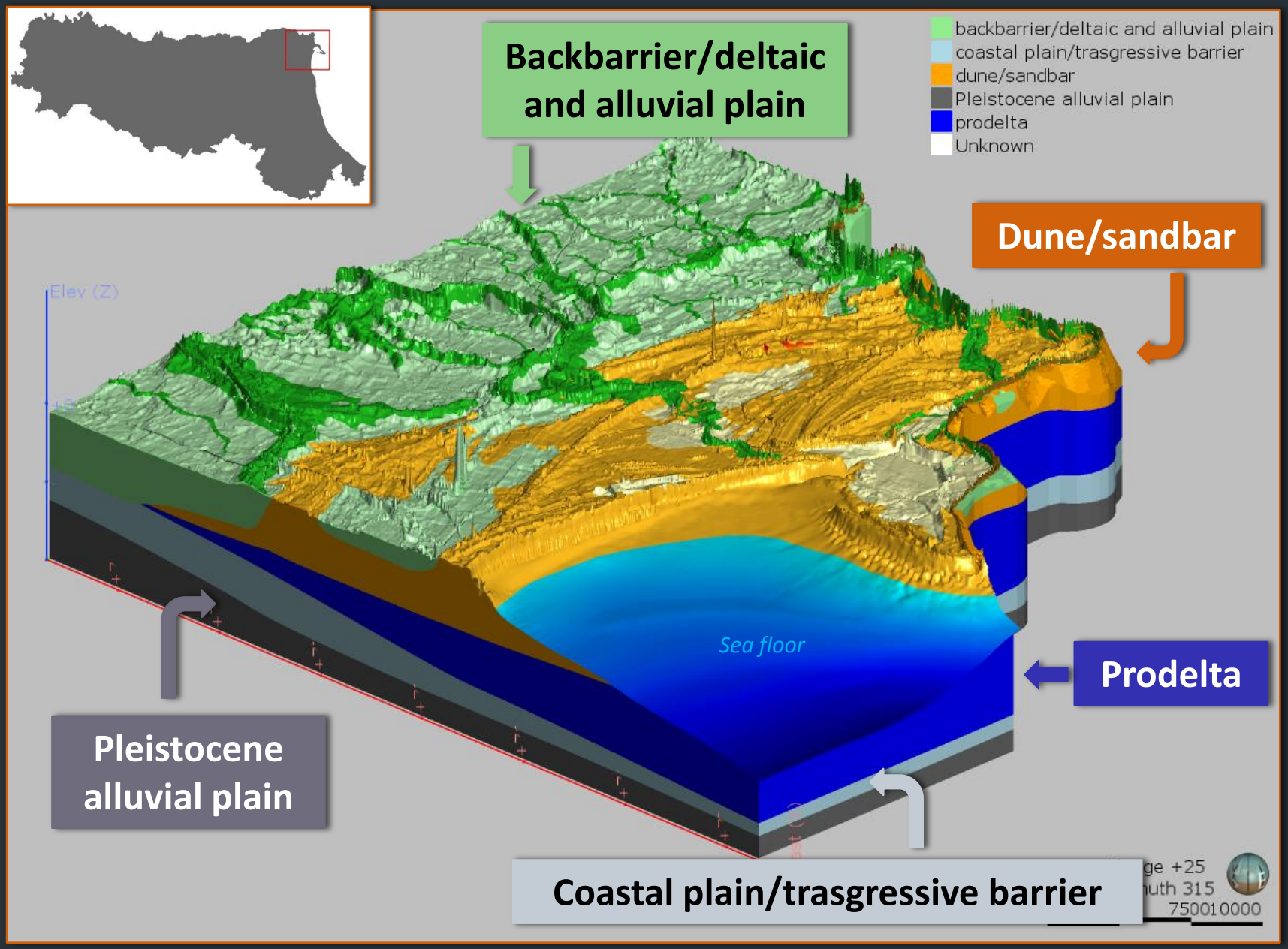
Geological unit:

- Lithology
- Depositional environments
- Chronology
- .....

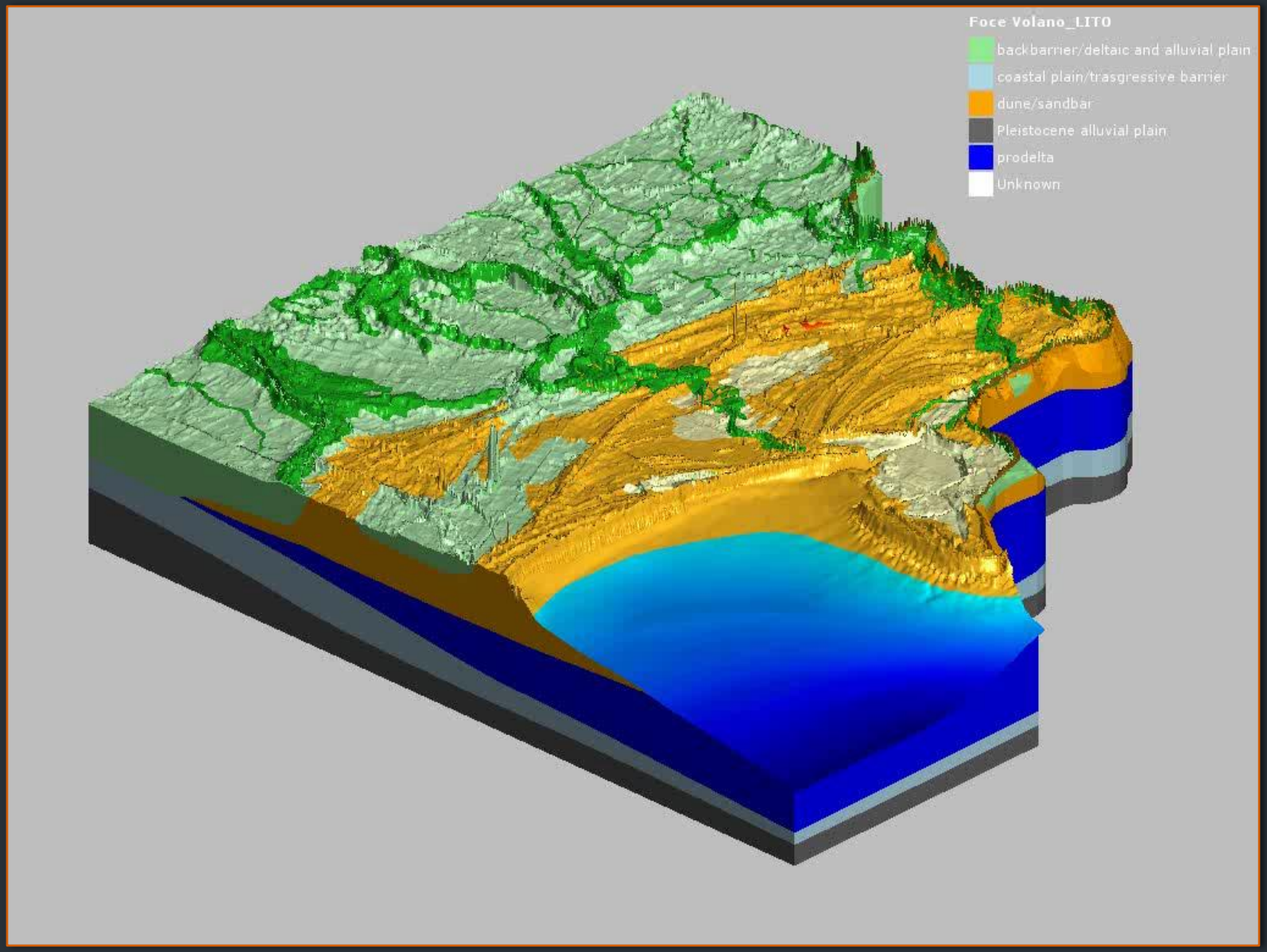


- Surface chronology
- Nature of the conctact (depositional or erosional)

Geological volume model



movie 1: **3D Geological Model of Po di Volano Delta**



Use of the 3D Geological Model

Thematic 3D Cartography

Geotechnical (CPTU data)

- Soil Behavior Type (SBT)
- Yield Stress Ratio (YSR)
- Factor of Safety against liquefaction (FS)

Hydrogeology

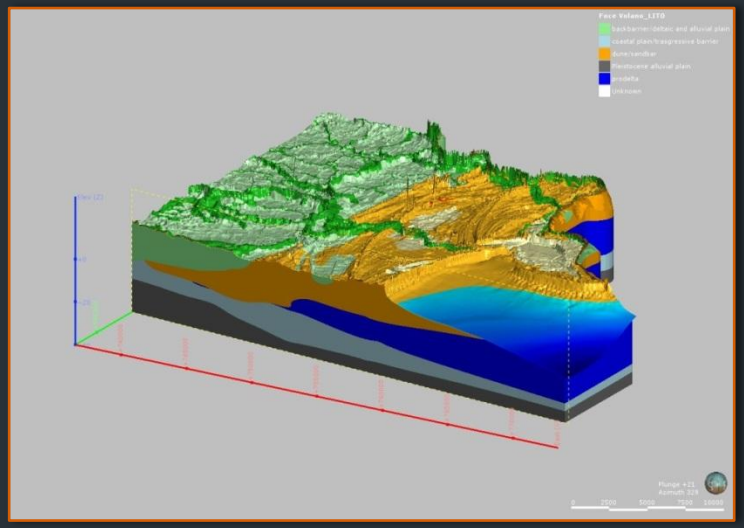
- Piezometric data of Coastal Phreatic Aquifer

Coastal Dynamics

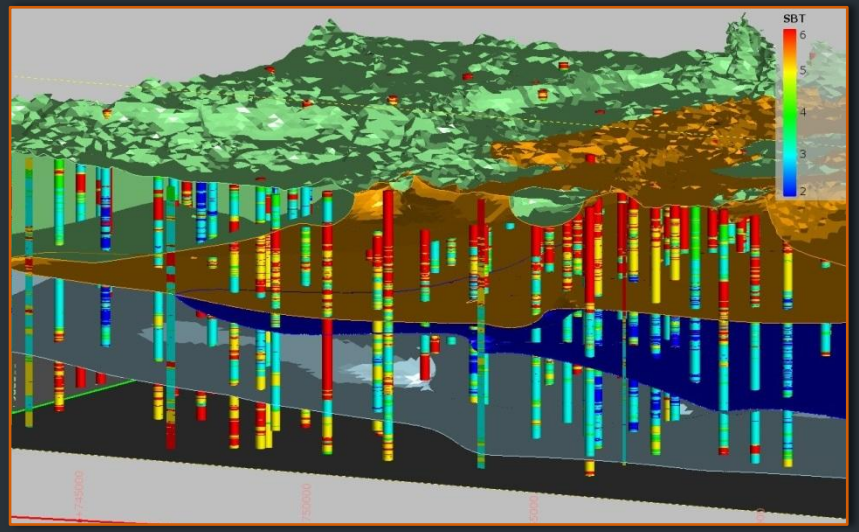
- Geometry and depositional evolution of delta lobes

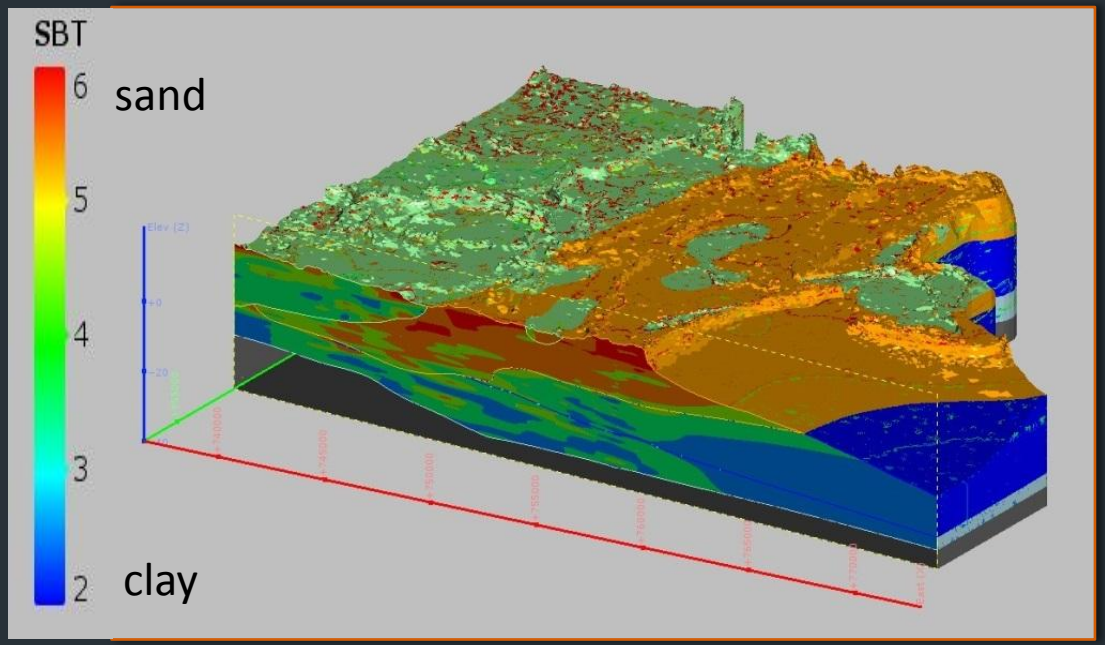
Soil Behavior Type (SBT) from piezocone pentration test (CPTU)

Geological model



CPTU => SBT (Robertson 2009)

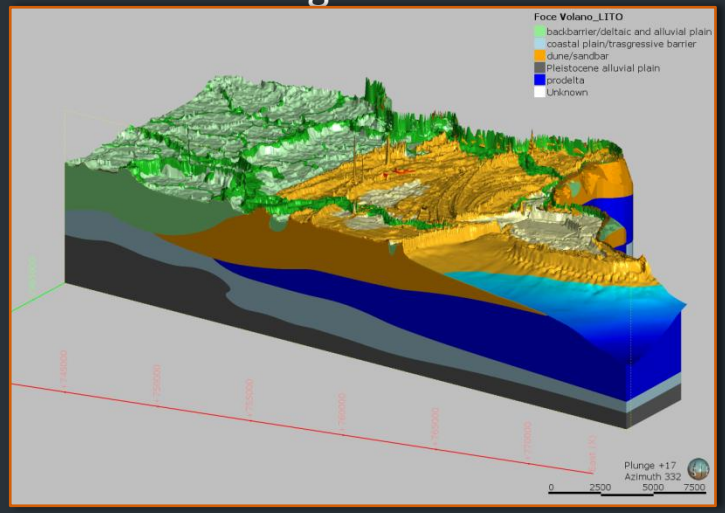




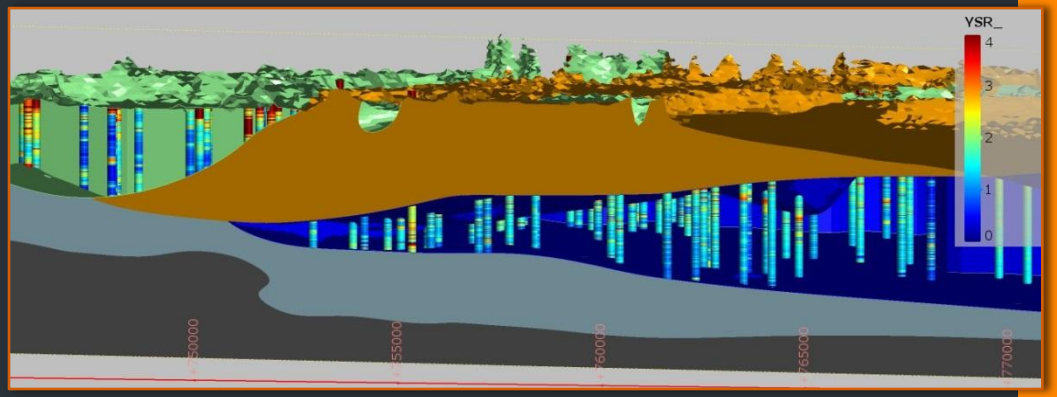
SBT values were interpolated inside each of the volumes.
The **lithological variations** within geological units, as example in the «dune/sandbar» unit (orange), can be appreciated.

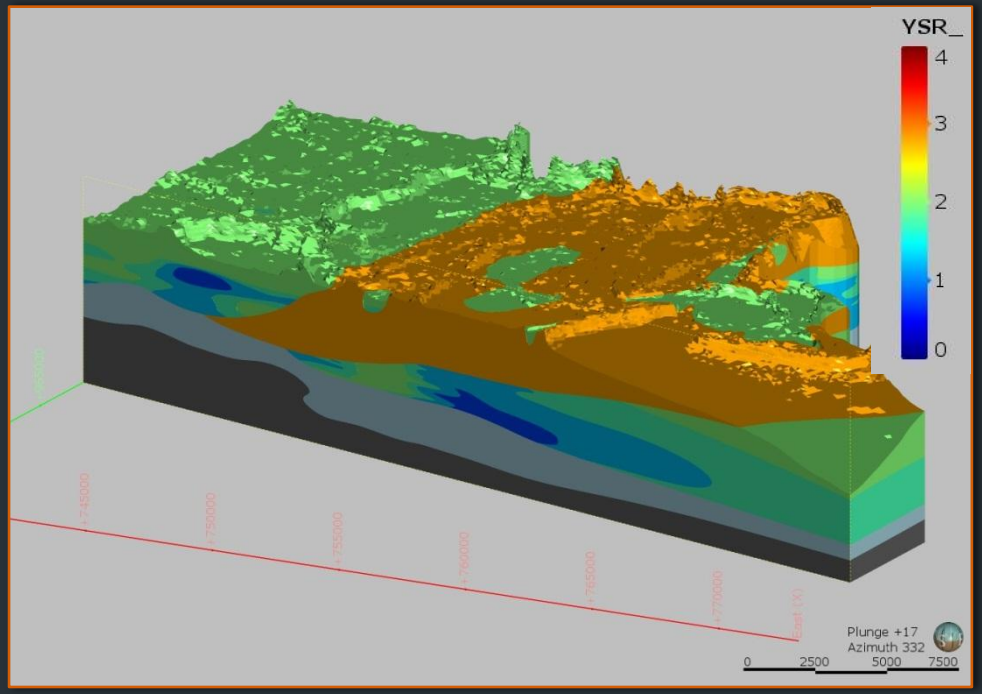
Yield Stress Ratio (YSR) from piezocone pentration test (CPTU)

Geological model



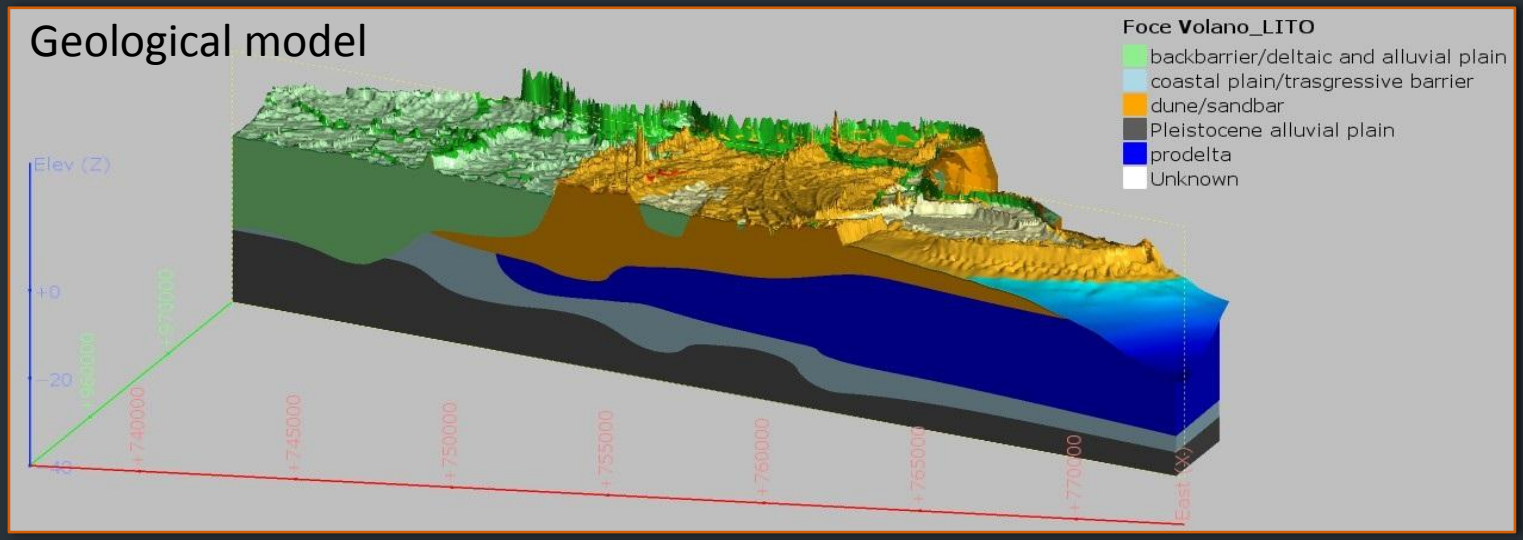
CPTU => YSR (Mayne 2014)

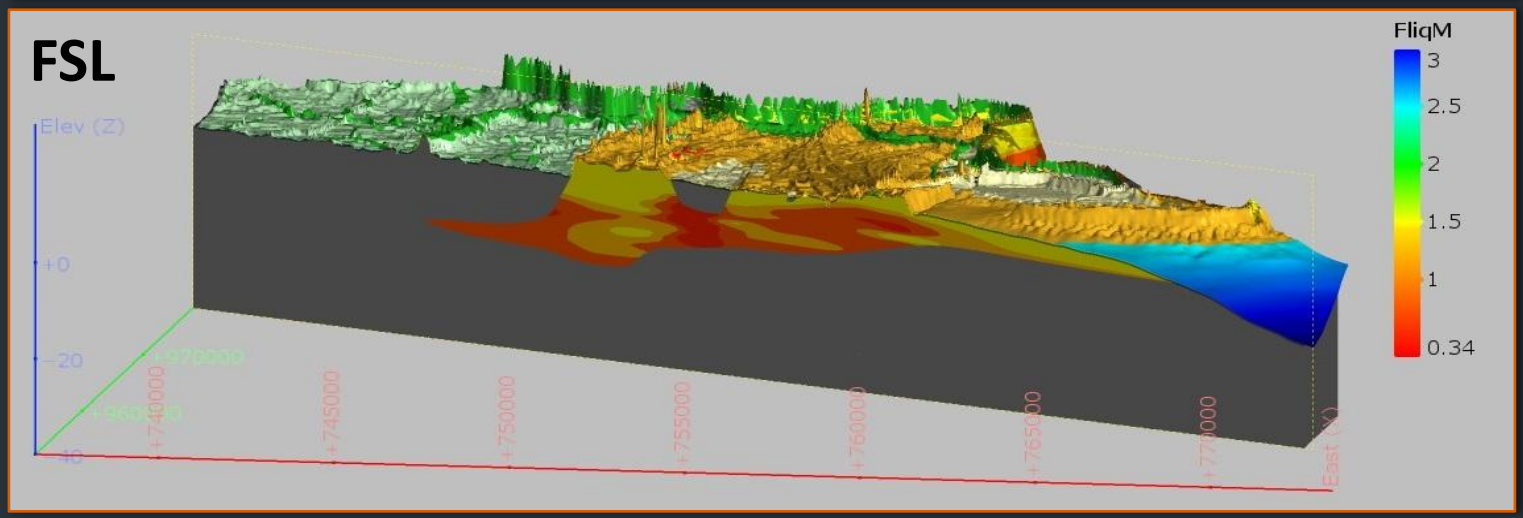




YSR represents the level of consolidation and it is interpolated within fine-grained units as «prodelta» and «backbarrier/deltaic and alluvial plain» units. Values below «1» (blue) can indicate under-consolidated deposits, prone to **settlements**

Factor of Safety against Liquefaction due to earthquekes (FSL) from CPTU

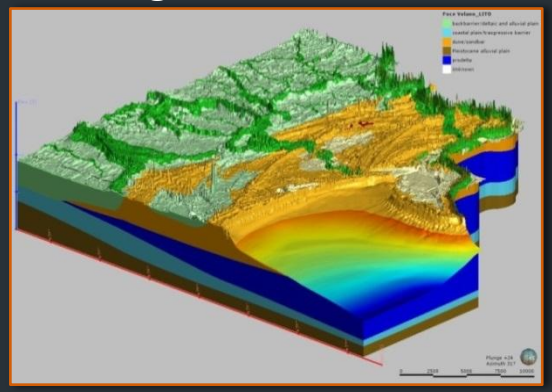


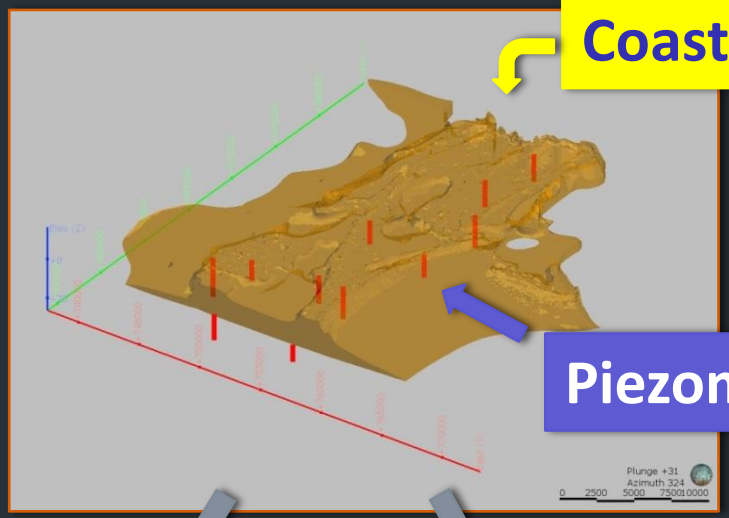


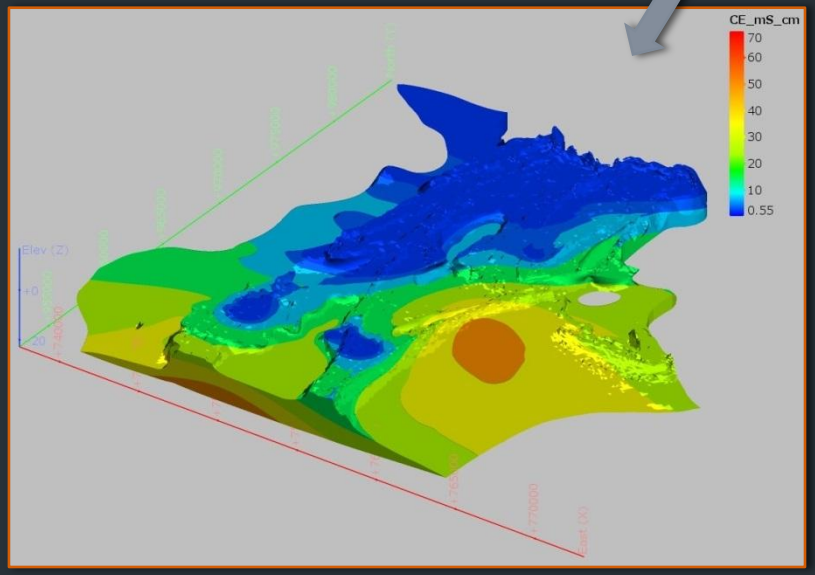
FSL is calculated (Robertson 2009) within the «dune/sandbar» unit; model shows volumes with values below «1» (red) prone to **liquefaction**

Salinity and temperature of groundwater

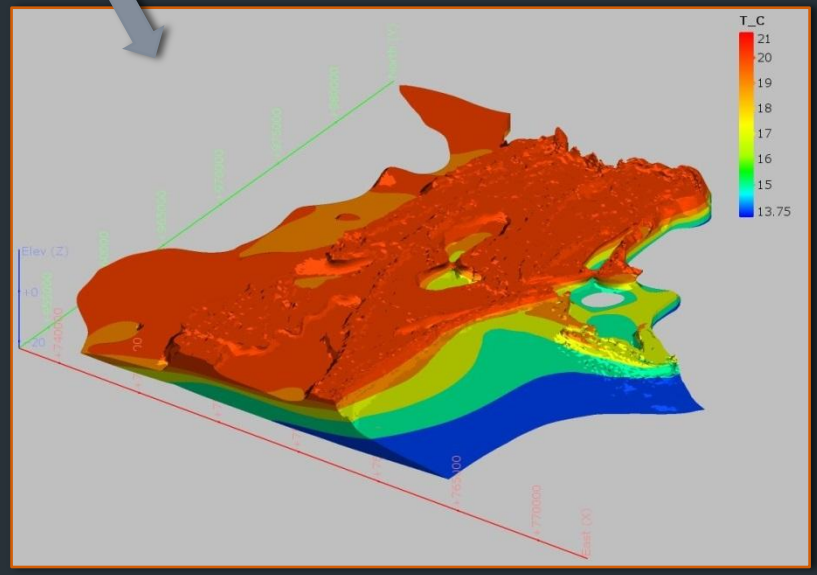
Geological model





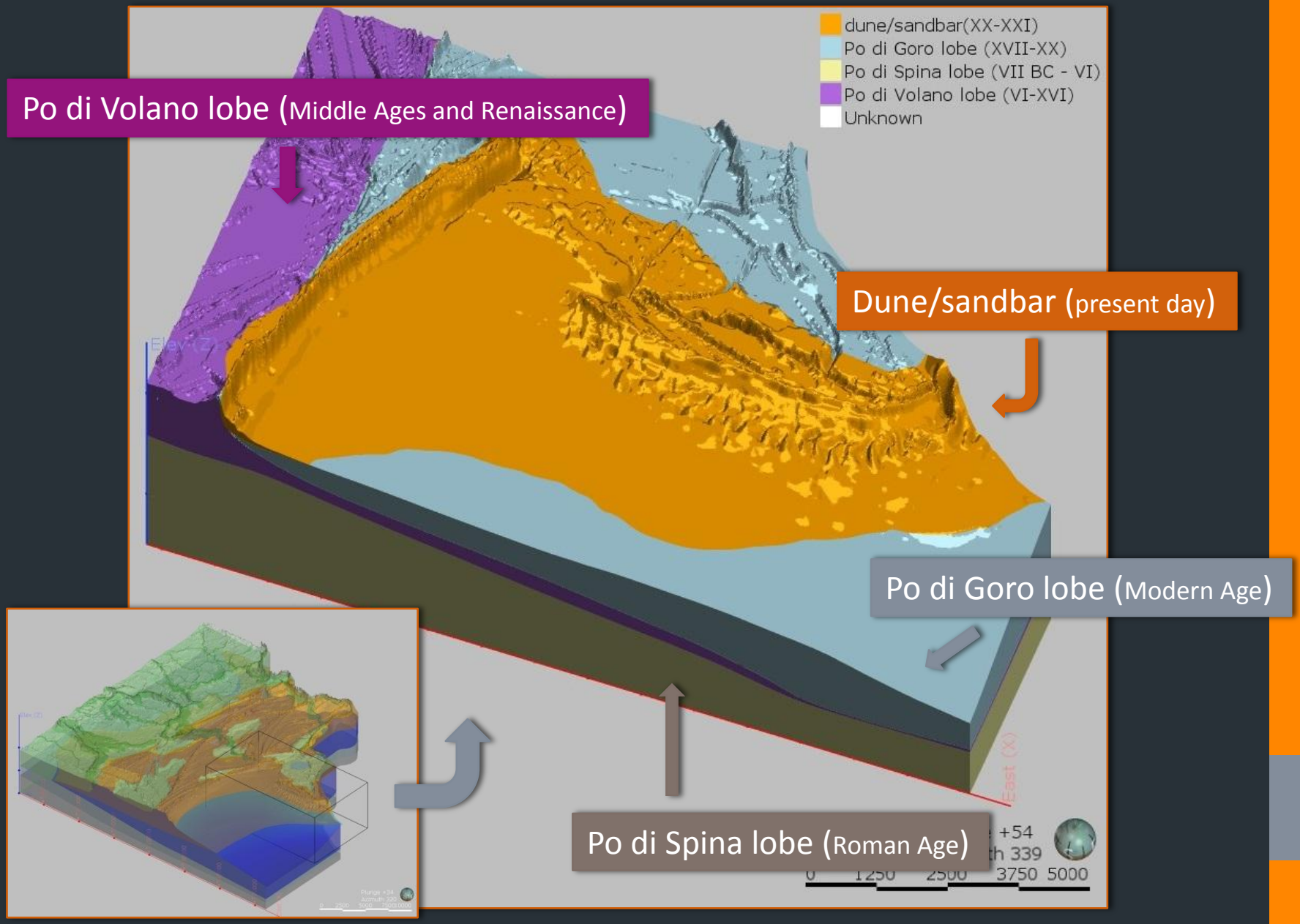


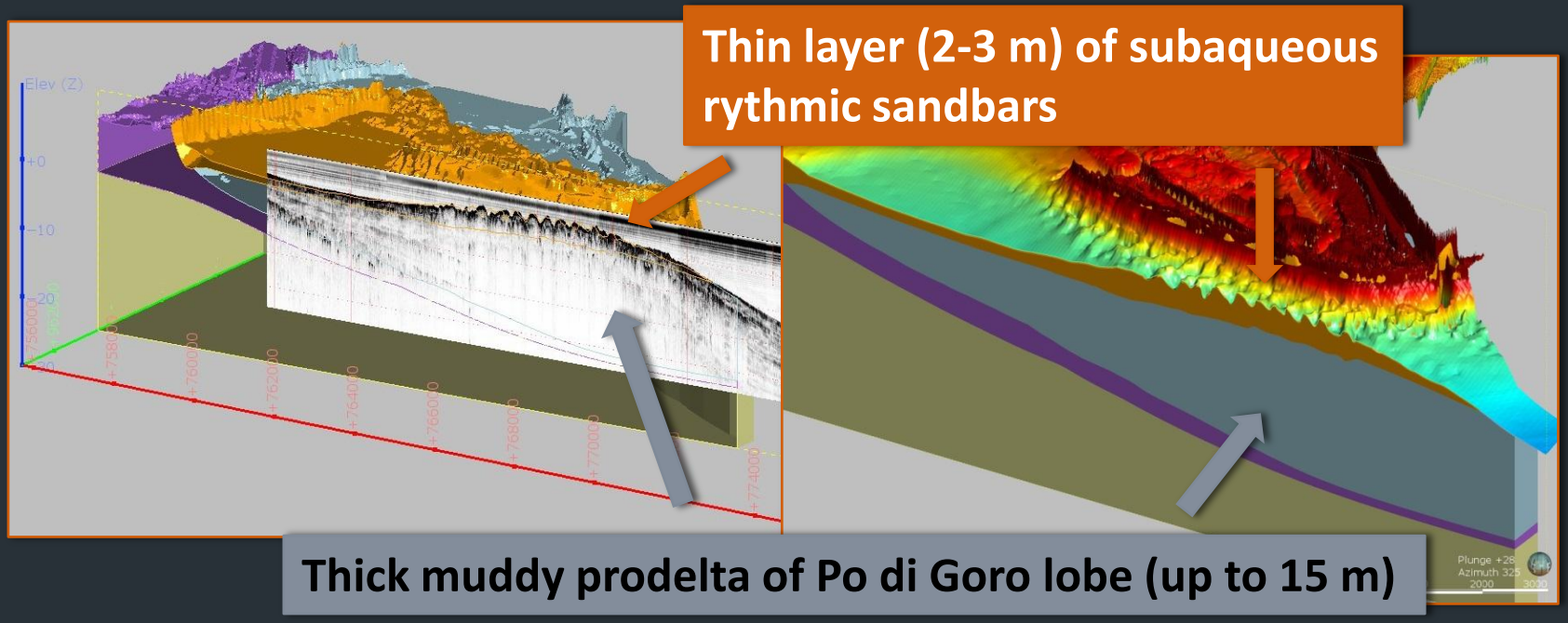
Electrical conductivity (EC)



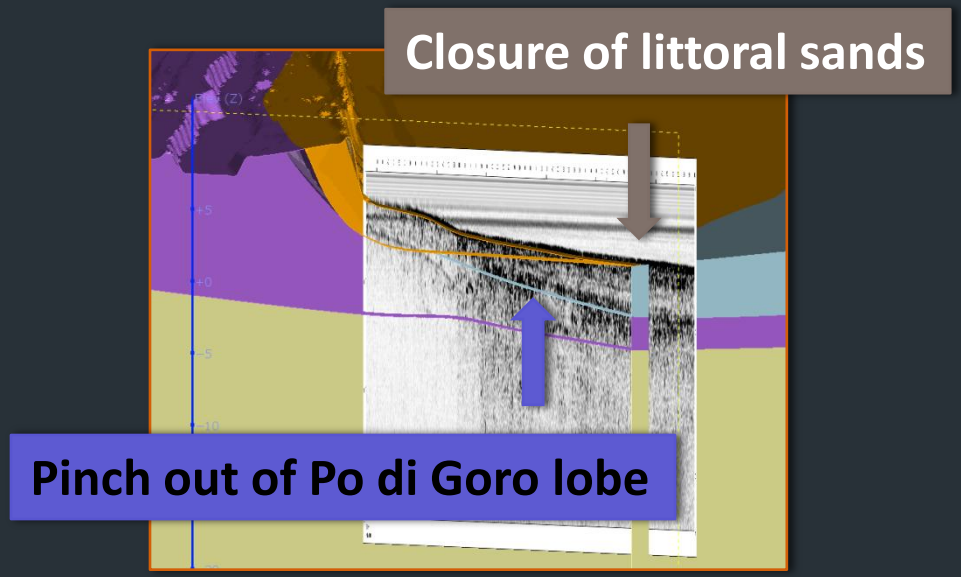
Temperature (T)

Recent delta lobes and littoral sand model

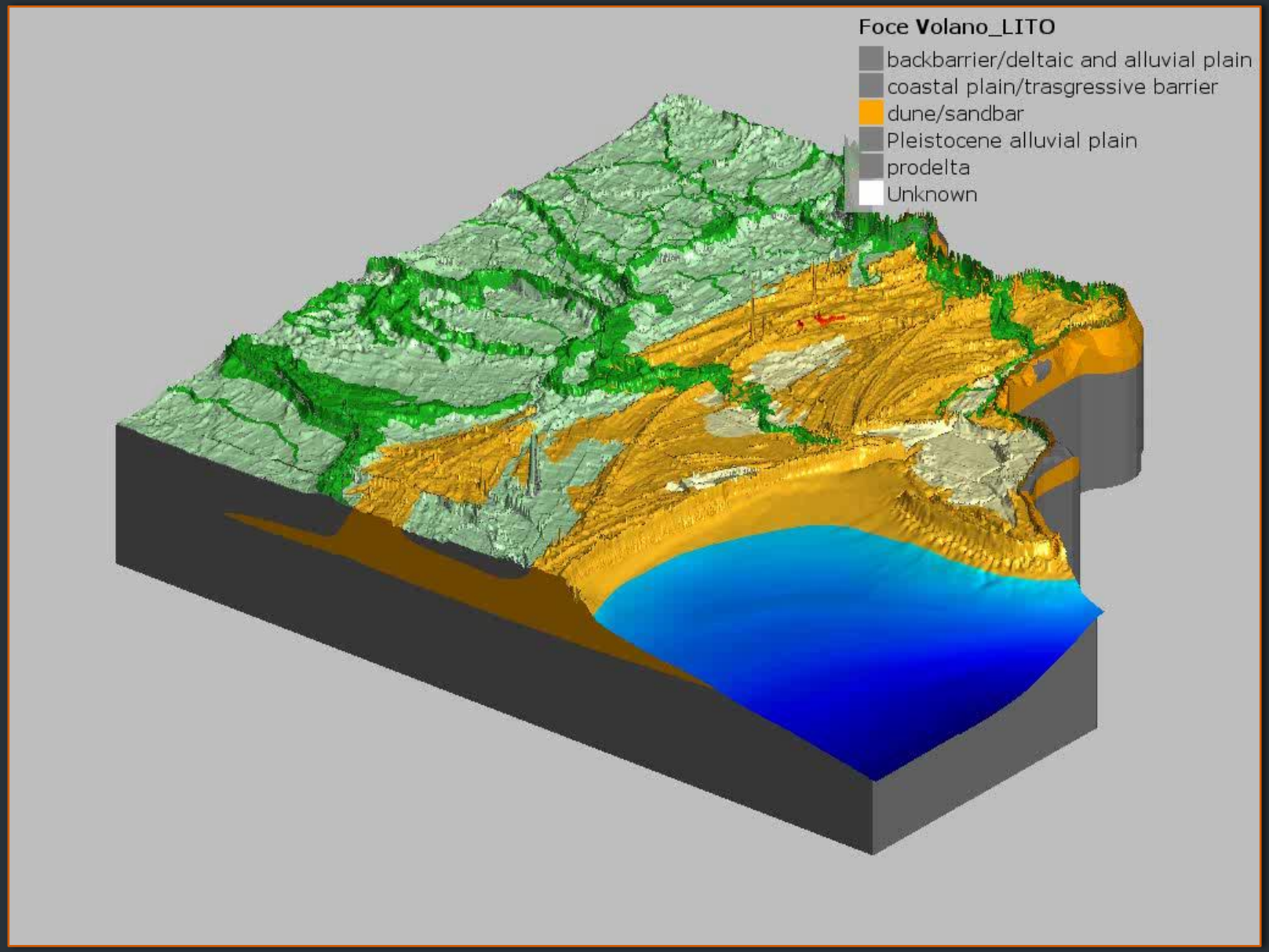




The model reproduces the sea-floor morphologies, thickness and geometric relationships of the units, by integrating detailed digital bathimetric models, a rich set of seismic profiles and corings.



movie 2: **Examples of application of 3D model**



Concluding remarks

We found significant advantages by employing 3D modeling:

- all geological and territorial data available can be integrated; models can be easily updated and implemented with new data
- models are realistic representations of the subsurface and support new evaluations for geologists
- derived thematic mapping yielded good results, opening up new possibilities for interesting future developments

Thank you for your attention

http://ambiente.regione.emilia-romagna.it/geologia

Leapfrog software by ARANZ Geo (New Zealand); main characteristics:

- Implicit modeling:

model is generated by computer algorithms directly from a combination of measured data and user interpretation (conceptual model). It is dynamic and it produces automatically surfaces from geological data. Advantages: faster, more flexible and better suited to making geological models

- Fast calculation:

FastRBF (Radial Basis Functions) algorithm is leapfrog engine ; it is an implementation of dual kriging, it deals with over 1 million of data points, quickly in ordinary computer

Notes

Soil Behavior Type is a classification based on CPT data that describe the mechanical characteristic/behavior of penetrated soil, correlating them to the main lithologies.

Robertson 2009 classification range from 2 to 6 for clay to sand, 1 stand for sensitive fine grained soil and gravelly or stiff deposits are 8 and 9

YSR= S'y(effective yield stress)/S'v0 (effective vertical stress)

FSL=CRR(cyclic resistance ratio of deposit)/CSR(cyclic stress ratio due to seismic shaking)