GeoMol

Assessing subsurface potentials of the Alpine Foreland Basins for sustainable planning and use of natural resources

Alpine SPACE

THIS PROJECT IS CO-FUNDED BY THE EUROPEAN REGIONAL DEVELOPMENT FUND

investing in your future

EUROPEAN TERRITORIAL COOPERATION

IL MODELLO GEOLOGICO 3D

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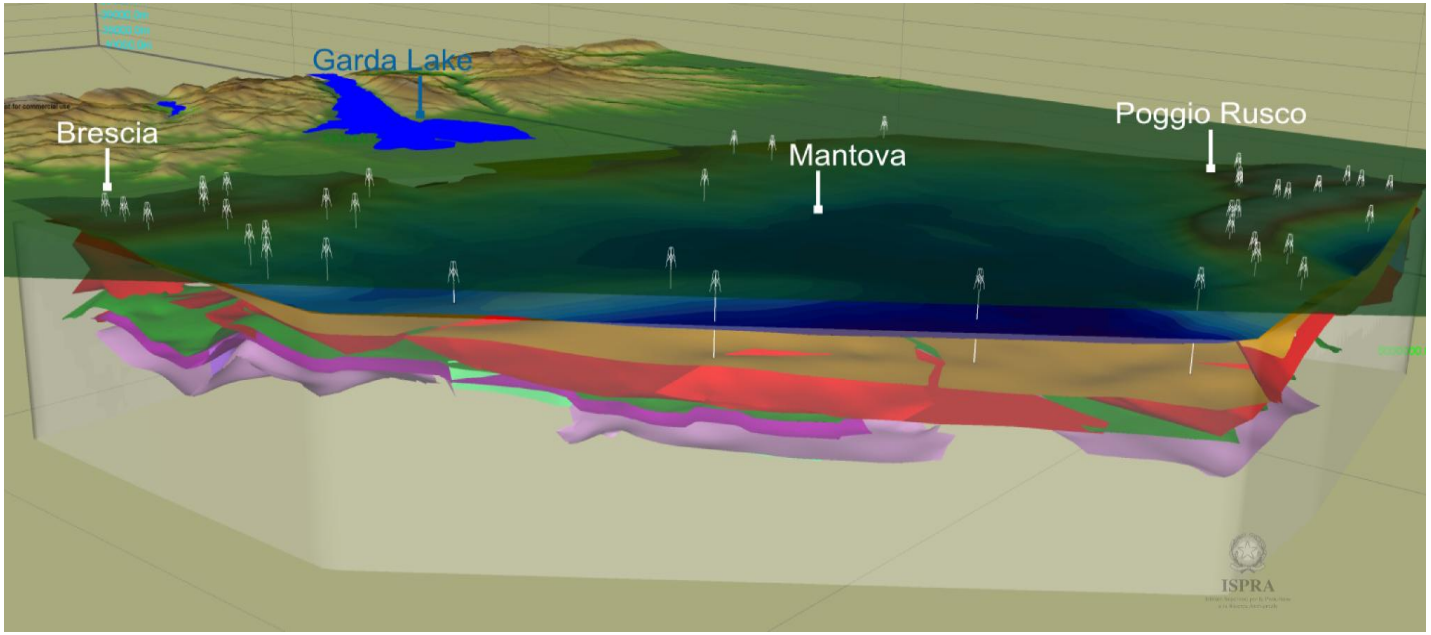
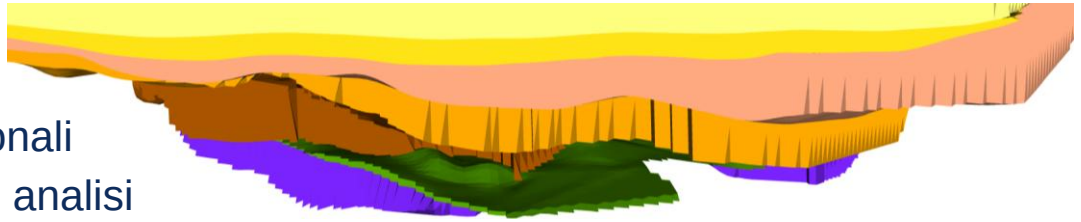
ISPRA – Servizio Geologico d'Italia



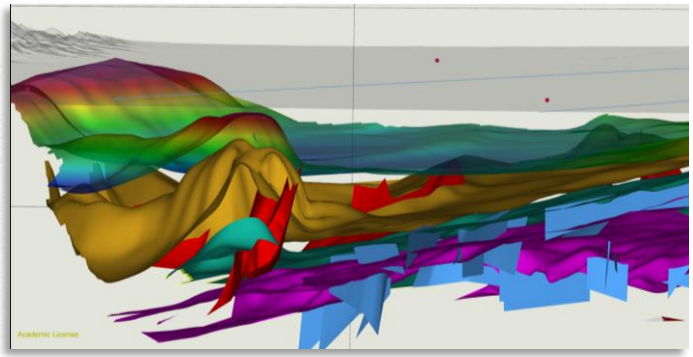
Bayerisches Landesamt für Umwelt
ISPRA Istituto Superiore per la Protezione e la Ricerca Ambientale
Geologische Bundesanstalt
RegioneEmilia-Romagna
REPUBLIQUE ET CANTON DE GENEVE
Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra
Swiss Federal Office of Energy SFOE
LAND OBERÖSTERREICH
GeoZS
Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra
Swiss Federal Office of Topography swisstopo
LGRB
brgm Géosciences pour une Terre durable
Regionalverband Bodensee-Oberschwaben
Regione Lombardia

Obiettivi del Progetto GeoMol



Modelli geologici 3D trans-nazionali/regionali basati su metodi comuni di costruzione e analisi

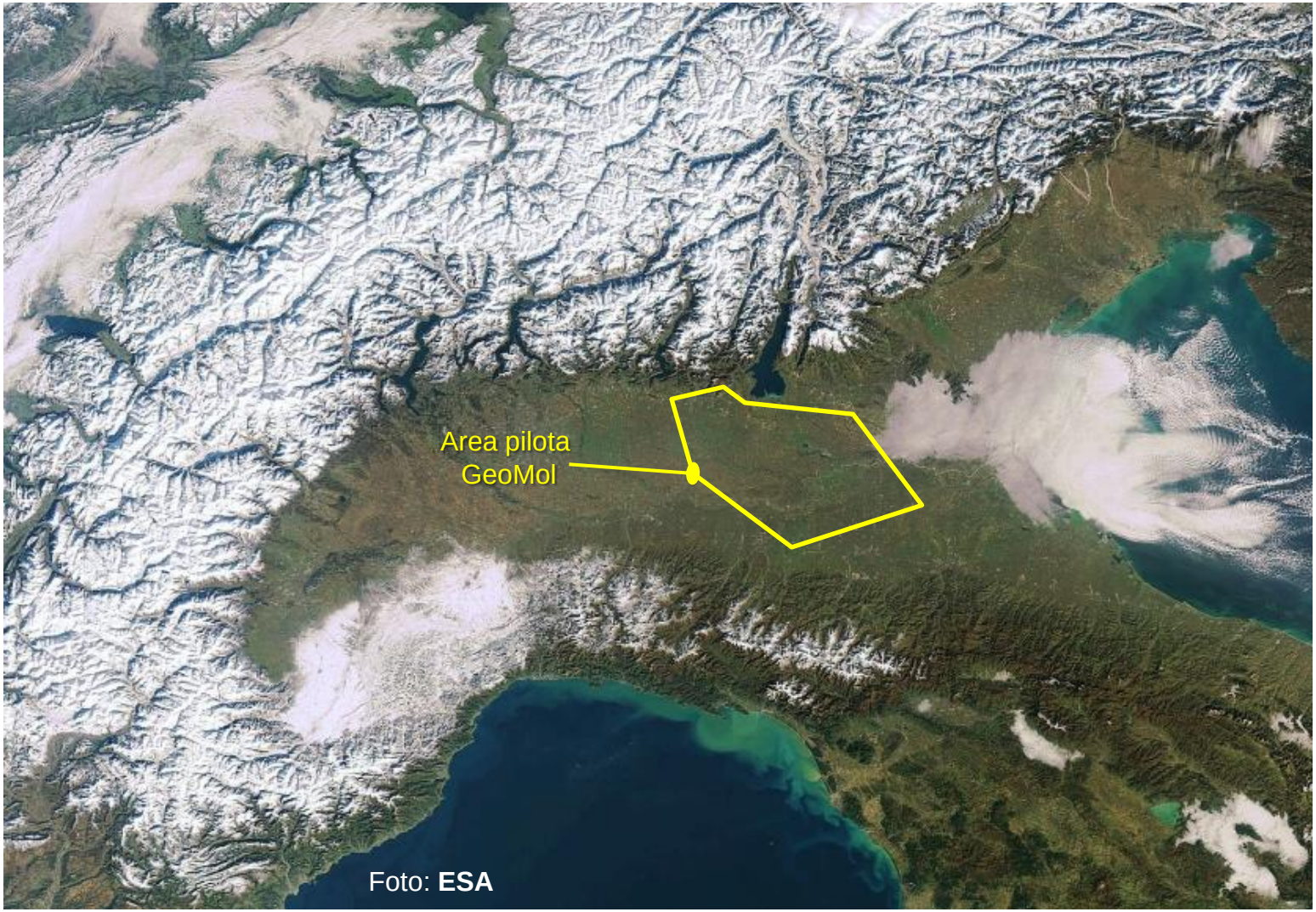
Area pilota italiana – Modello geologico per la valutazione della **geotermia** con particolare attenzione alle **strutture tettoniche** (area del terremoto 2012)

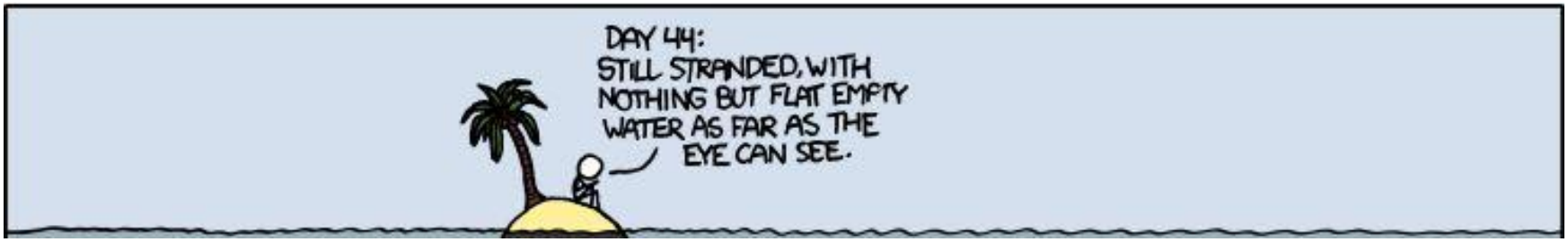


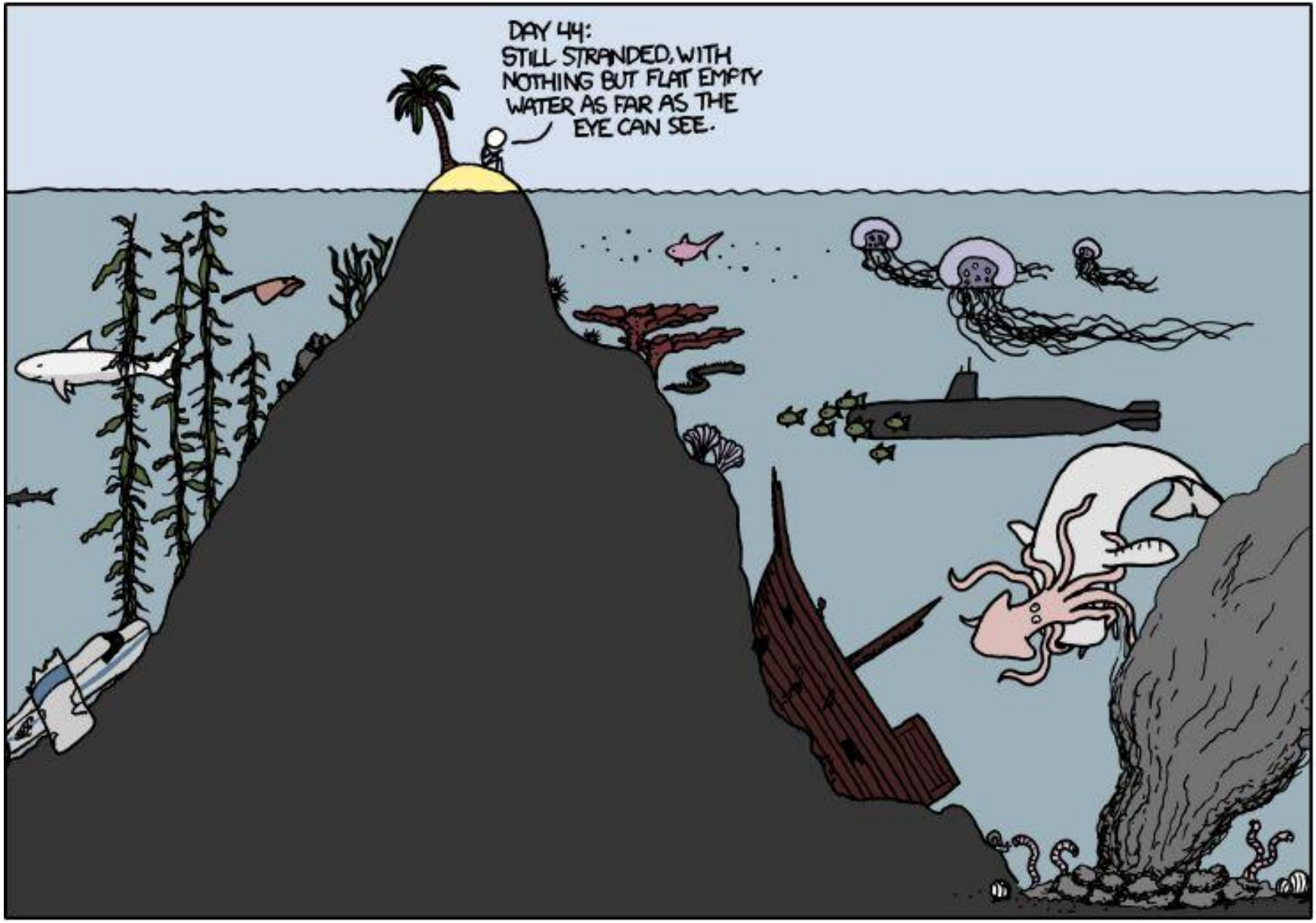
Modello geologico 3D è un prerequisito per una

- Conoscenza delle strutture geologiche nella loro interezza (volumi e faglie)
- Valutazione delle potenziali risorse del sottousolo
- Supporto alla valutazione degli impatti

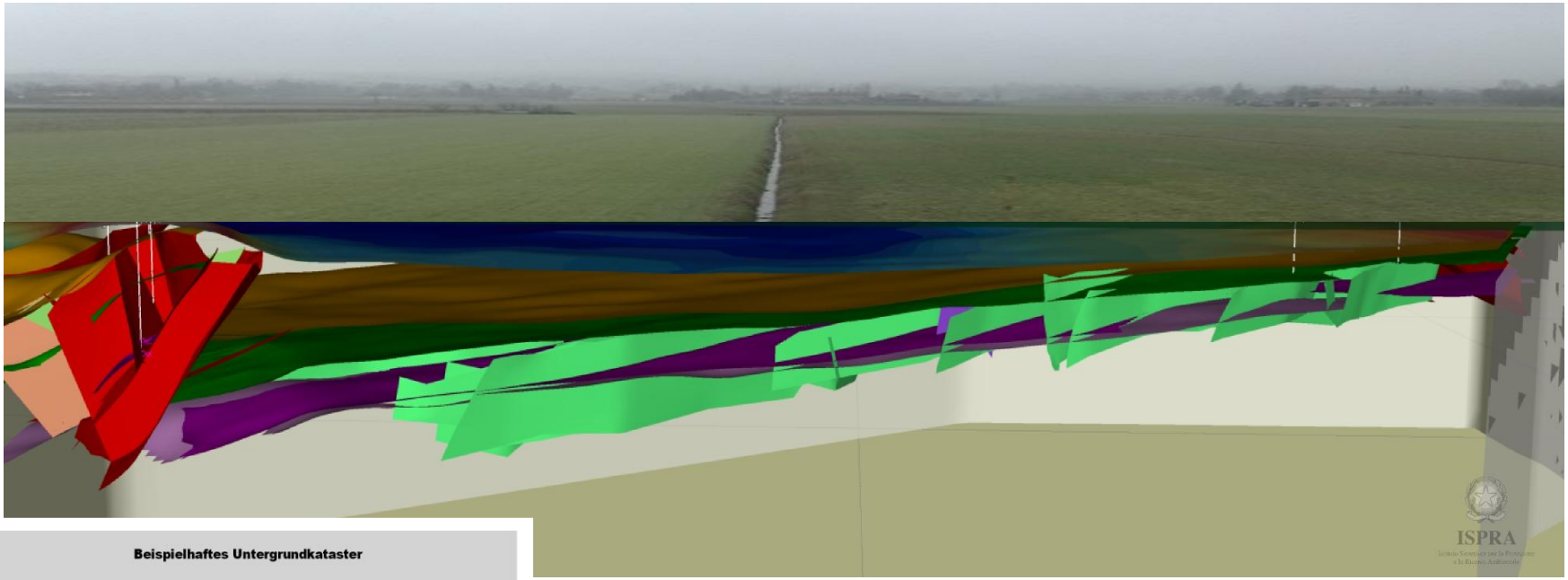
Alpine Foreland Basins - modelli geologici 3D in aree di pianura

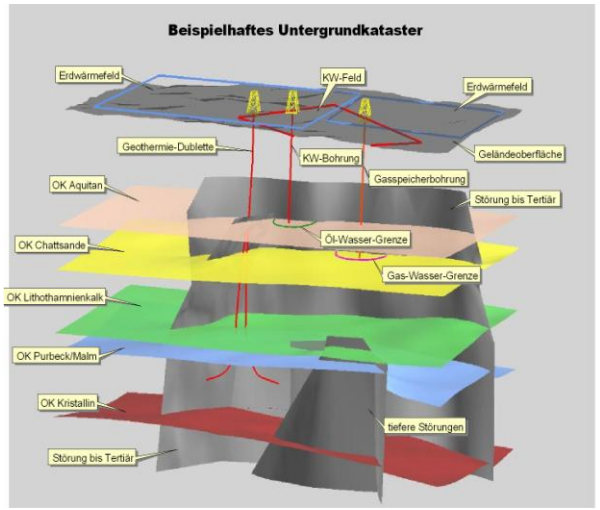






Alpine Foreland Basins - modelli geologici 3D....





...che supportano la richiesta di pianificazione nell'utilizzo delle risorse del sottosuolo

Autorizzazione senza limite di profondità - "*from soil to hell*"

Modelli 3D possono supportare la zonazione verticale
→ consentendo anche utilizzi concorrenti

modello geologico-strutturale 3D è un modello geometrico che descrive relazioni spaziali tra corpi geologici

coerente con i dati

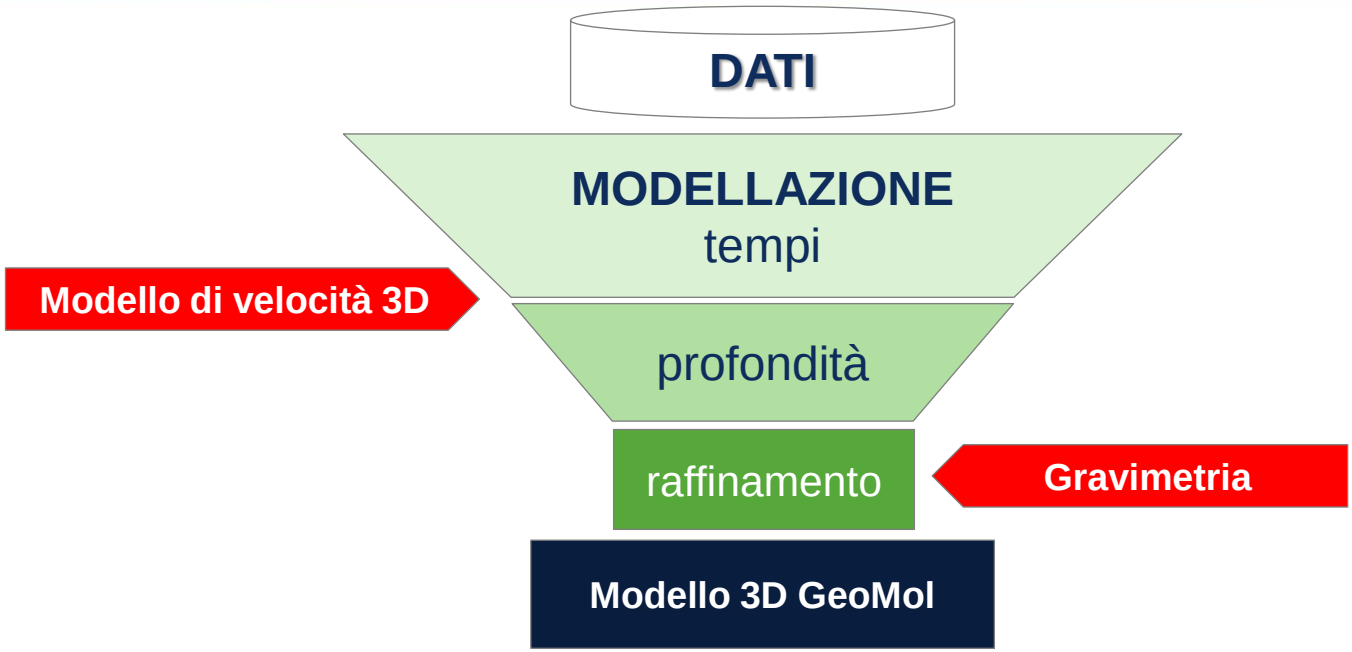
dipendente “solo” da ipotesi sicure

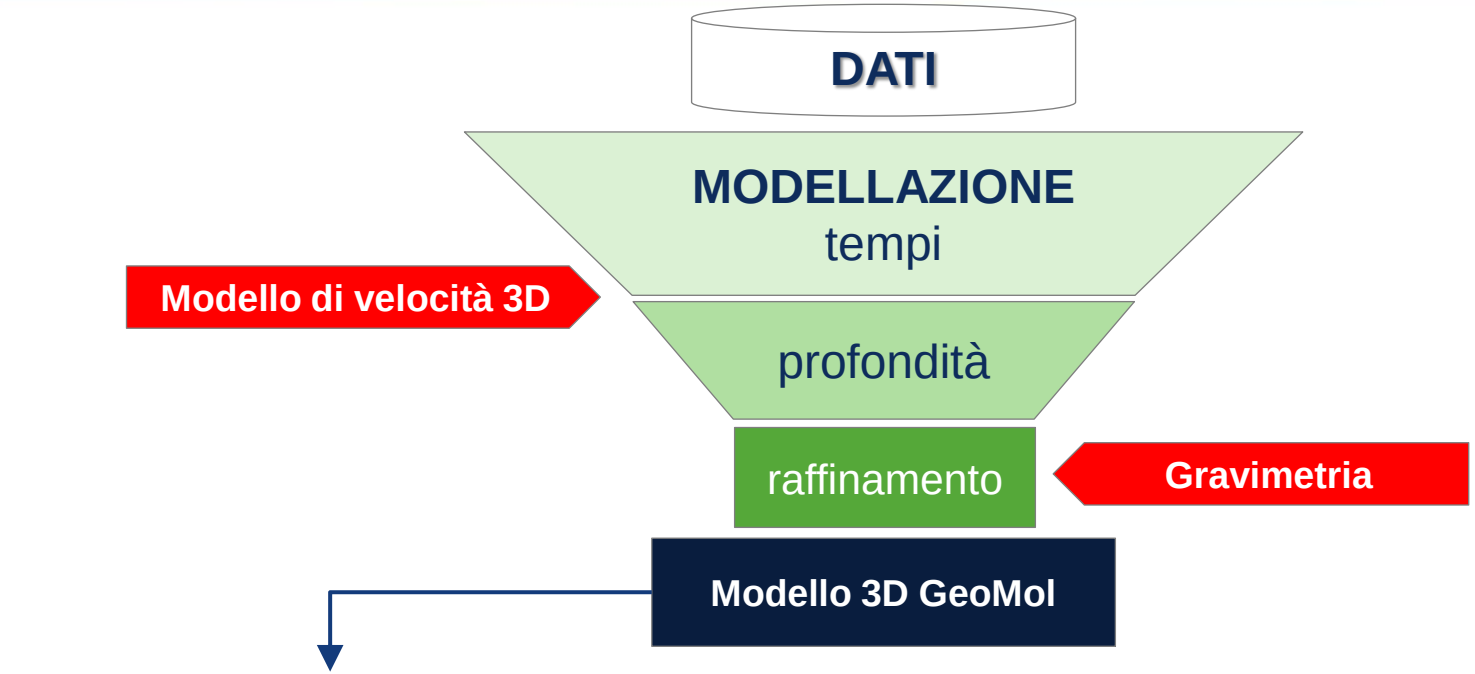
predittivo

descrivendo l’incertezza

evidenziando problemi di interpretazione

supportando ulteriori analisi

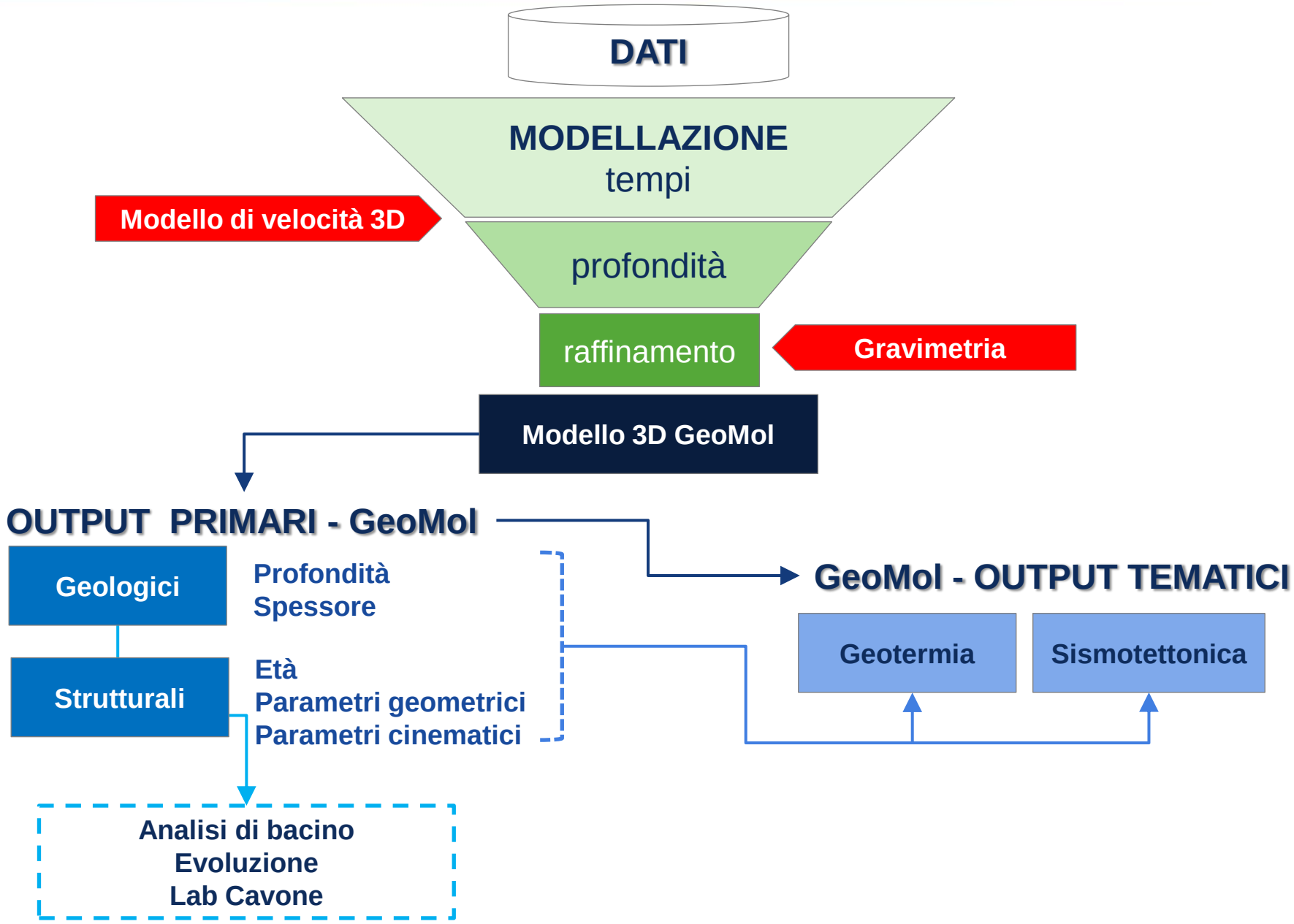


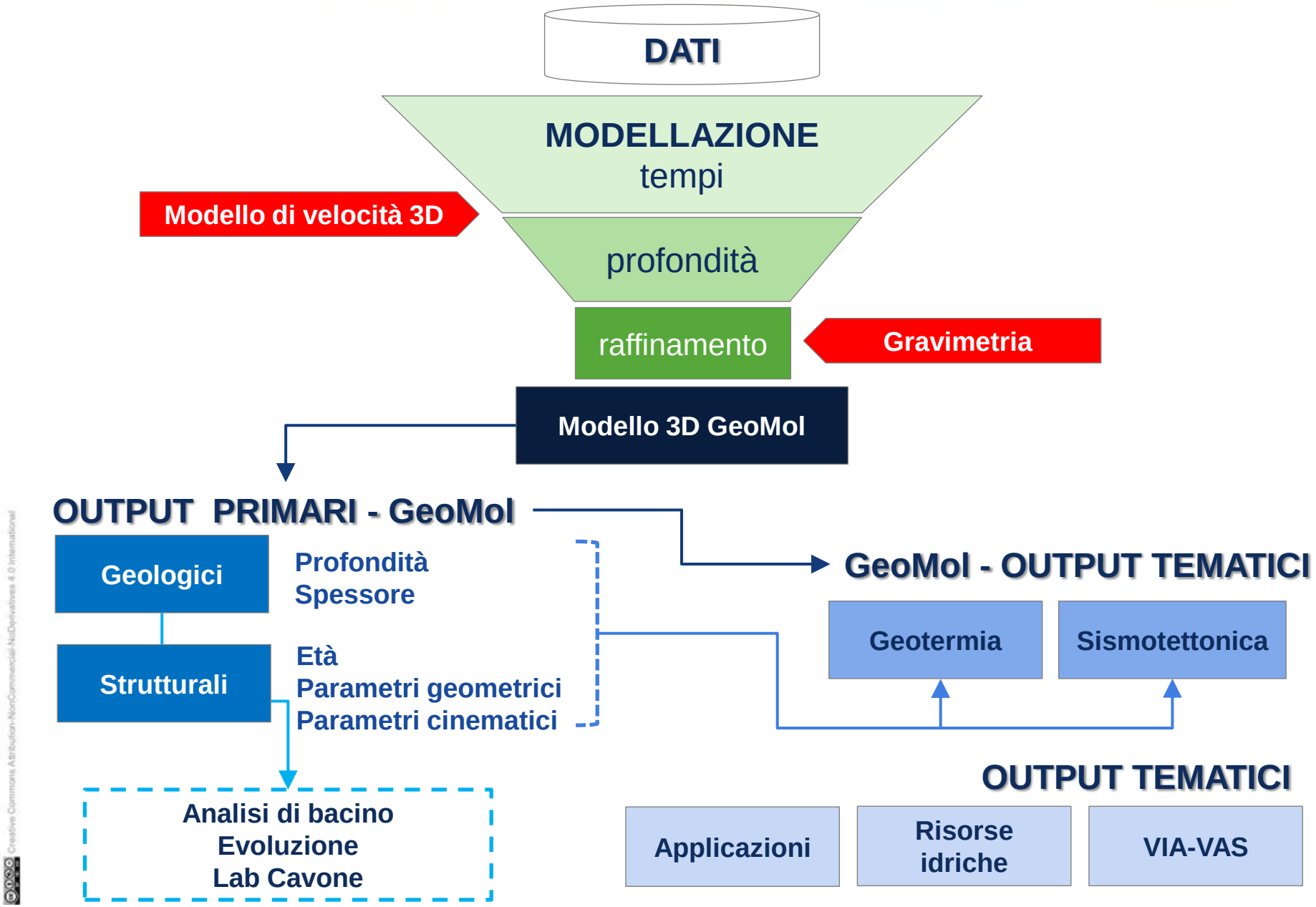


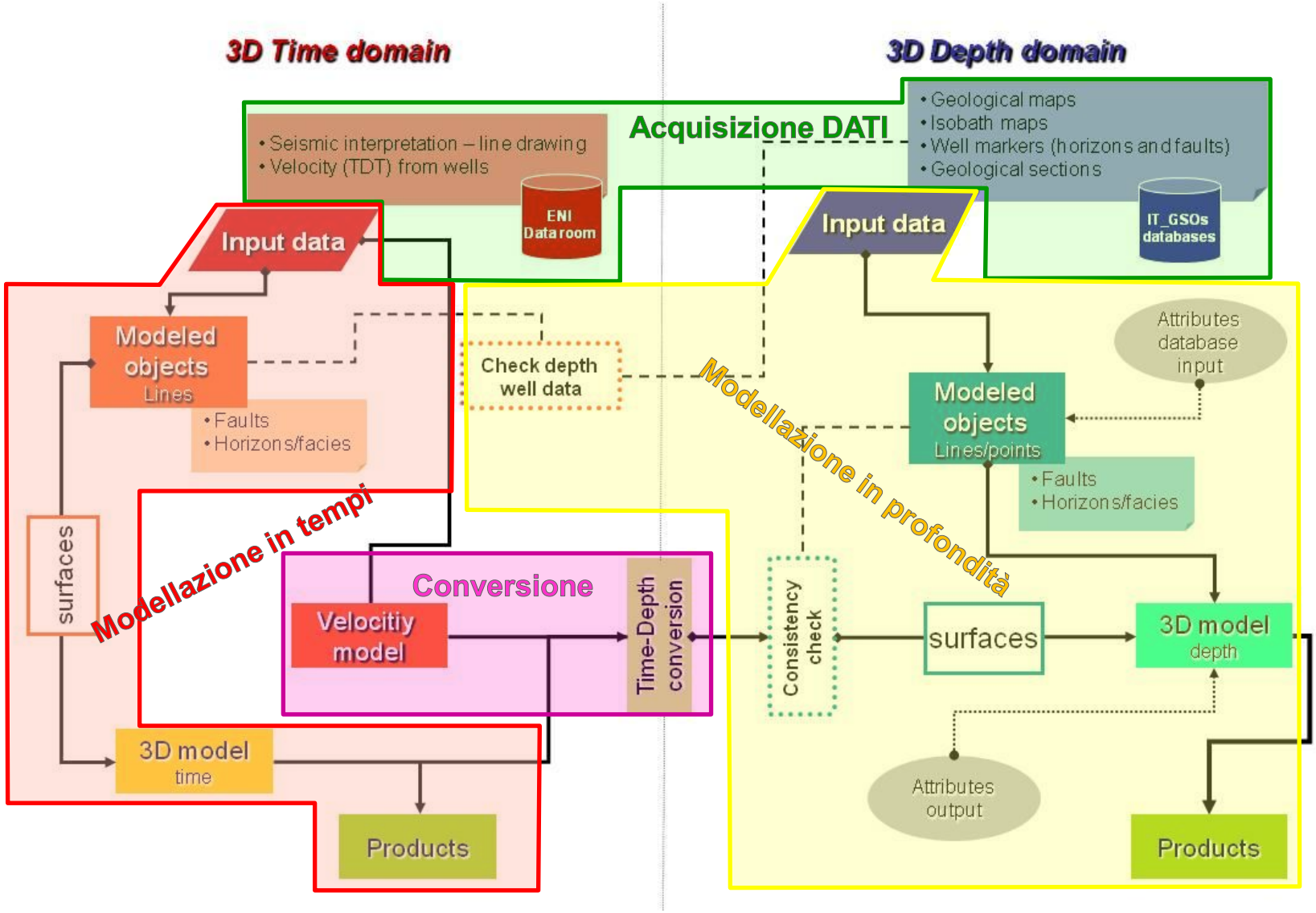
OUTPUT PRIMARI - GeoMol

- **Geologici** — Profondità, Spessore
- **Strutturali** — Età, Parametri geometrici, Parametri cinematici

Analisi di bacino
Evoluzione
Lab Cavone





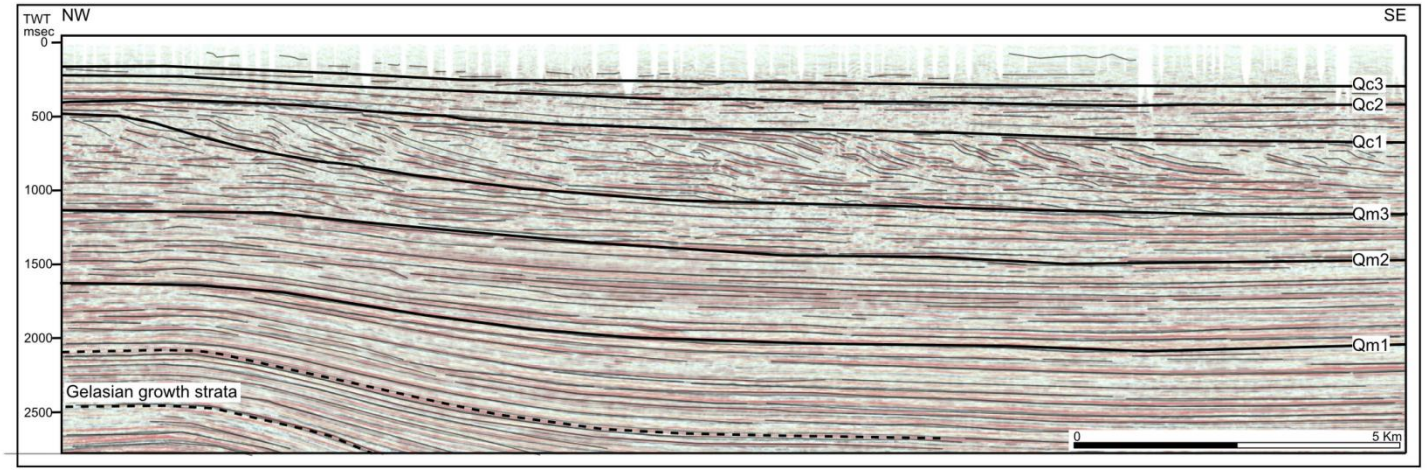


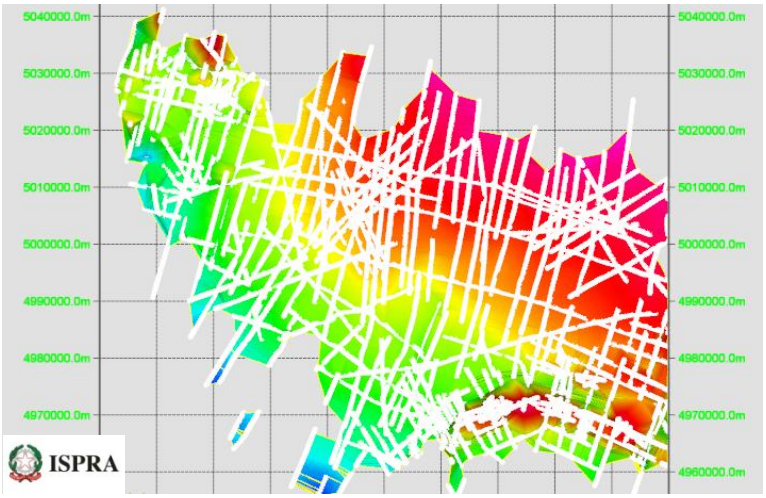
Maesano et al. (2014) Rend. SGI

La costruzione del modello 3D

Dall'interpretazione 2D al modello in tempi

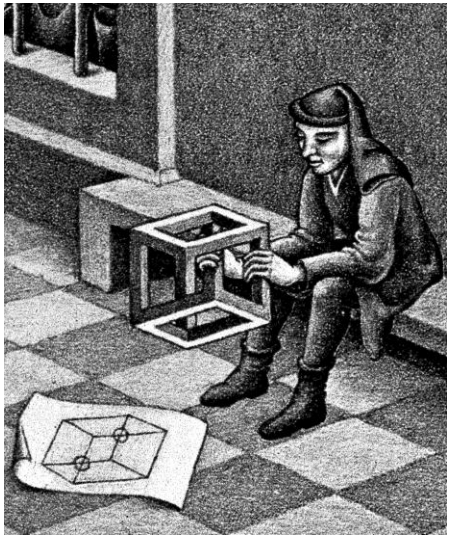
TIME DOMAIN





Orizzonti: 2.620.239 punti

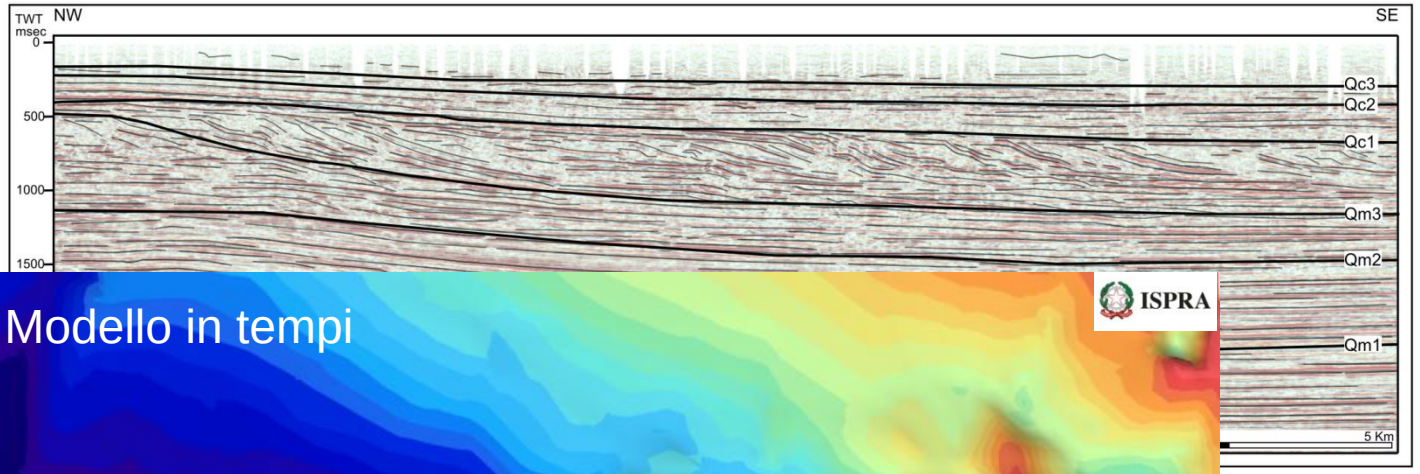
Faglie: 5369 punti

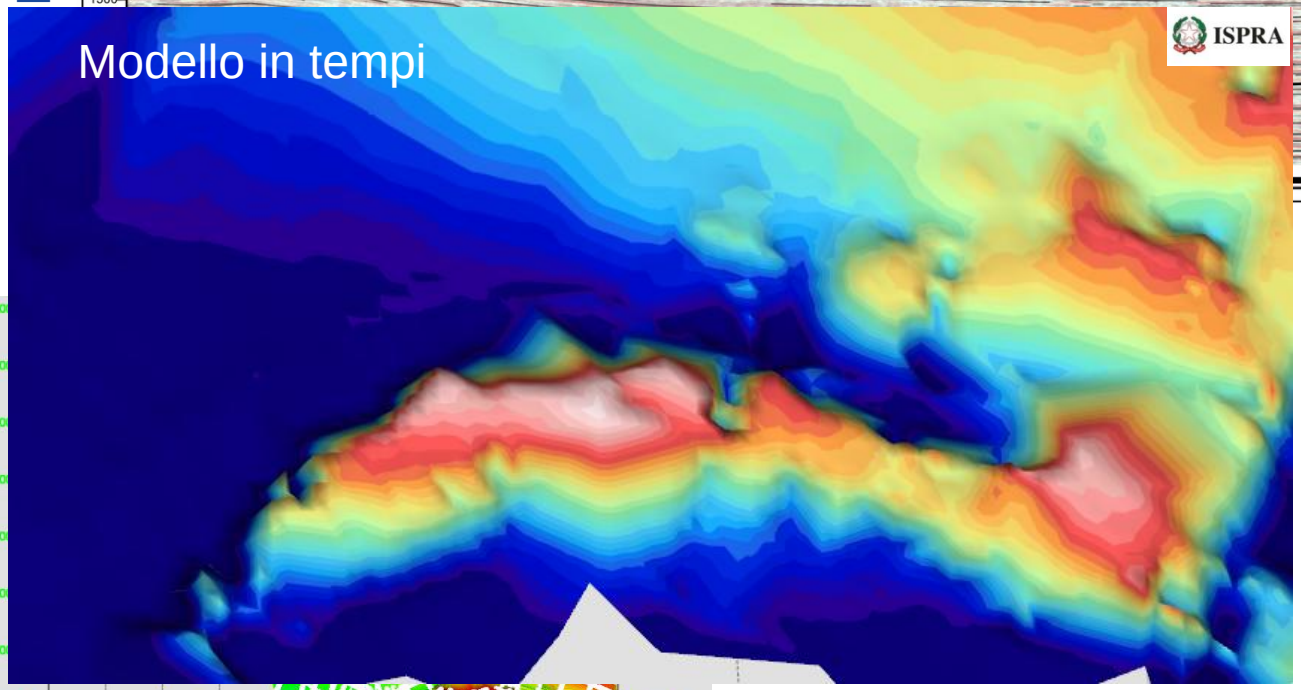


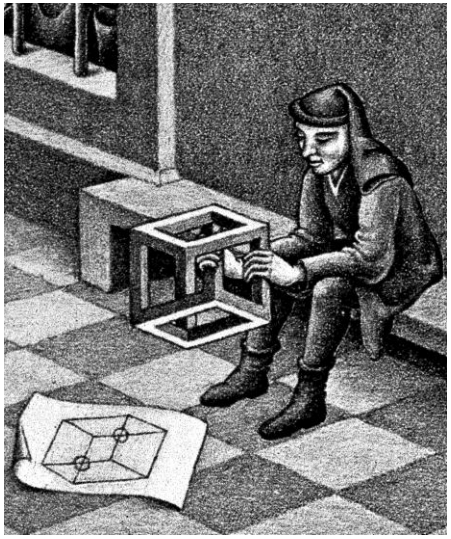
La costruzione del modello 3D

Dall'interpretazione 2D al modello in tempi

DOMAIN



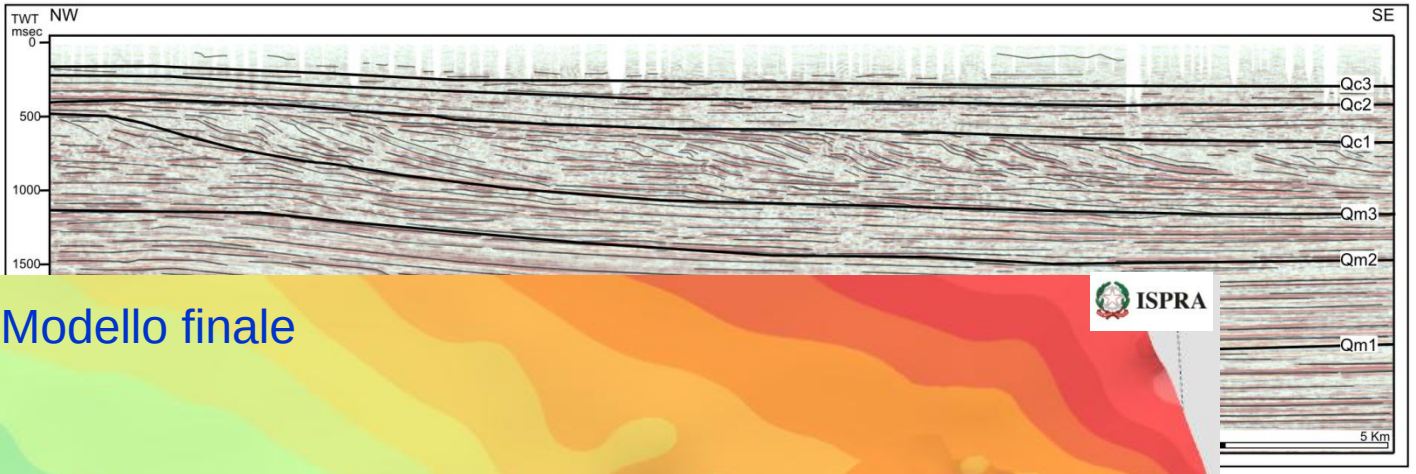


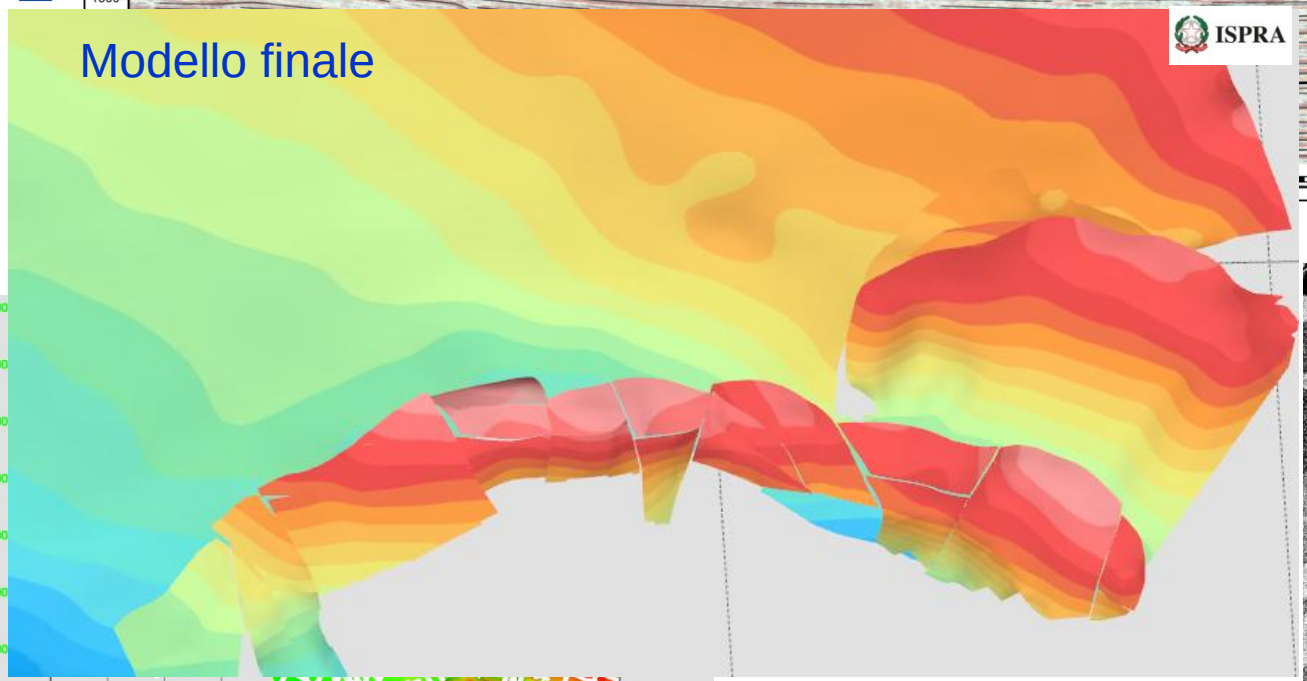


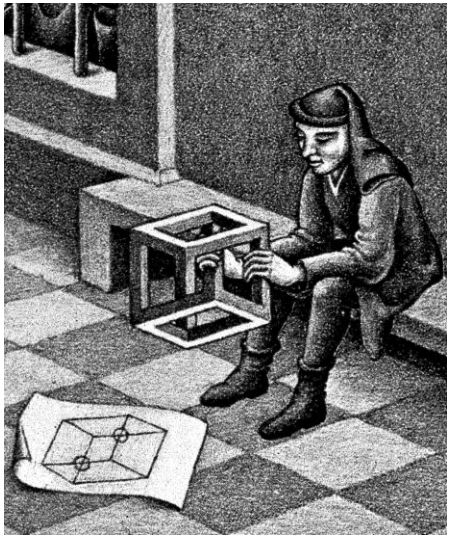
La costruzione del modello 3D

Dall'interpretazione 2D al modello in tempi

DOMAIN



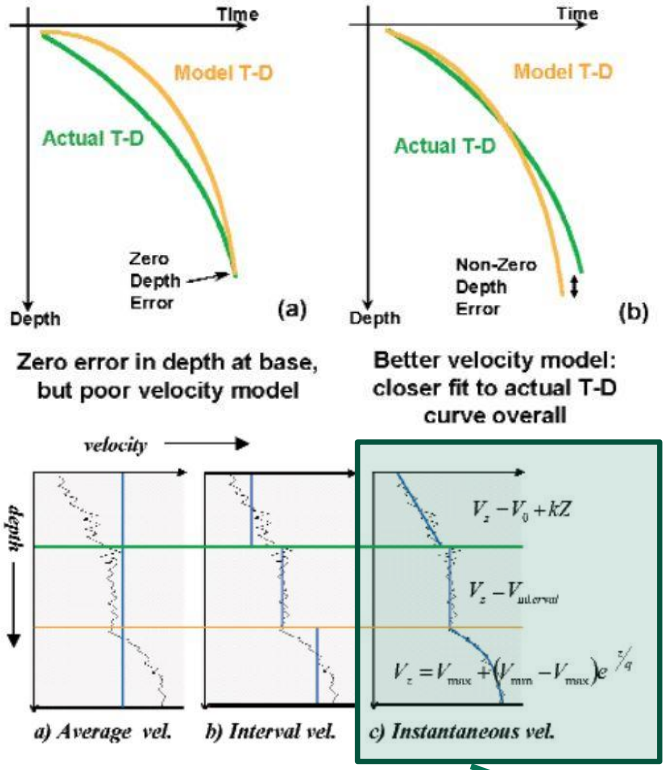


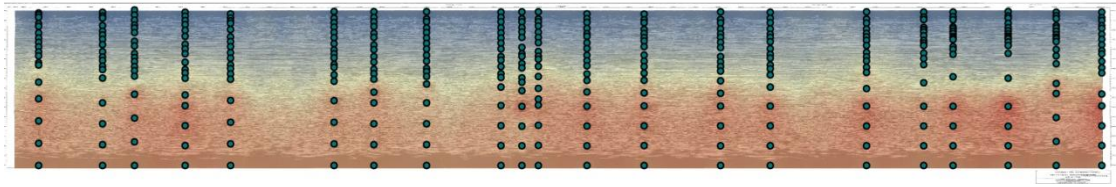


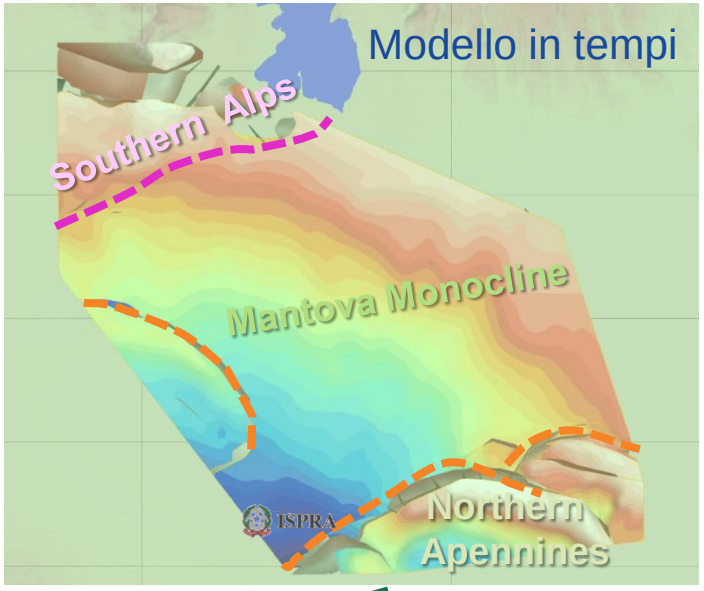
Il modello di velocità

Dal modello in tempi al modello in profondità

Conversione in profondità: problematiche e strategie



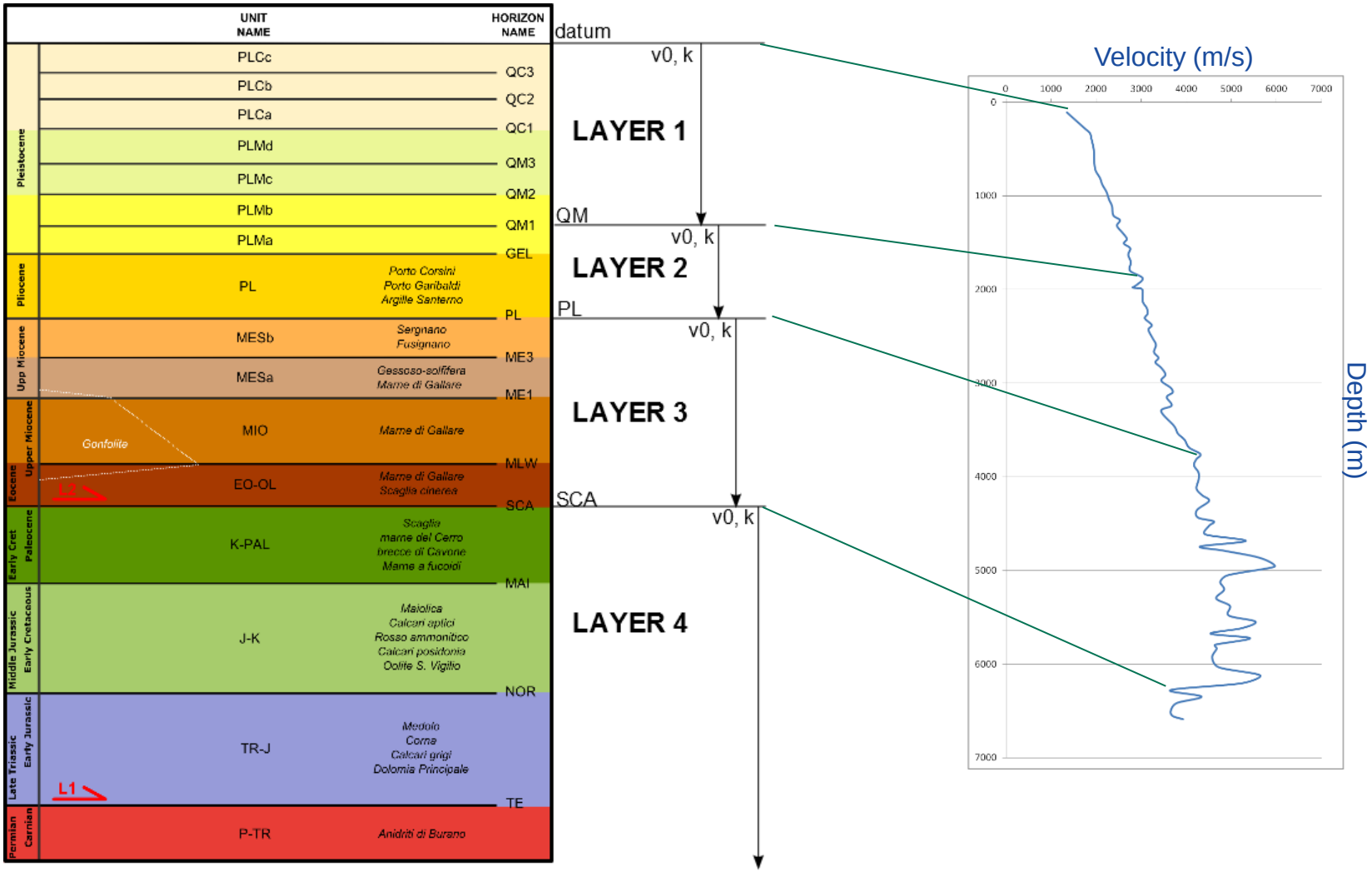




Modello di velocità 3D

Il modello di velocità

Dal modello in tempi al modello in profondità



La conversione in profondità

Dal modello in tempi al modello in profondità

GeoMol wells database

Extract velocity data for each stratigraphic interval

Analisys of well velocities to obtain V0 and k

Interpolate velocity (kriging/spline/IDW)

Interpolate gradient (kriging/spline/IDW)

Spatial overlay of v0 and k values on the [x,y,twt] ascii (horizon/fault surface)

GeoMol 3D model (time domain)

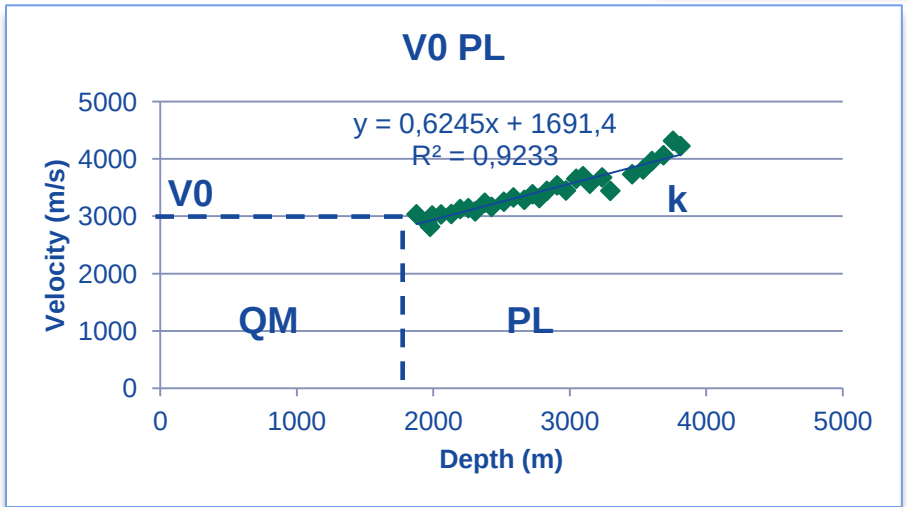
Depth conversion using istantaneous velocity

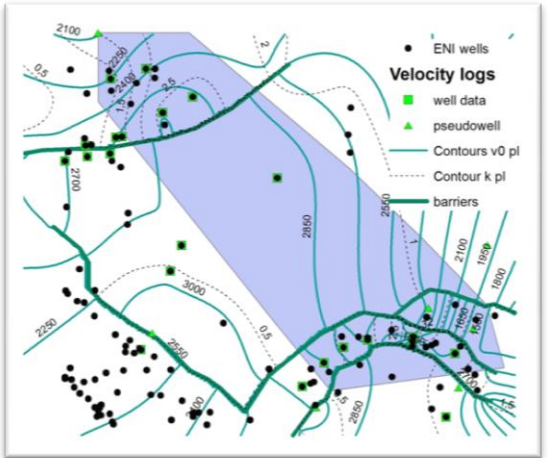
$$V(z) = V_0 + kz$$

$$V(z) = dz / dt$$

$$Z_n = Z_{n-1} + V_{0_n}(e^{k_n \Delta t} - 1) / k_n$$

Marsden 1992

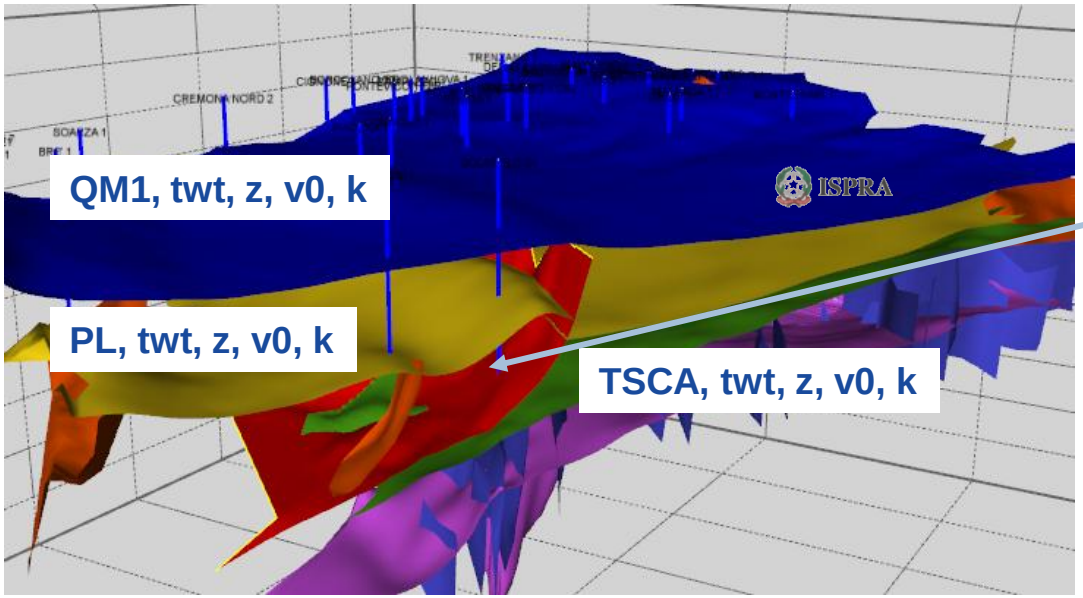




La conversione in profondità

Dal modello in tempi al modello in profondità

L'algoritmo di conversione in profondità è stato appositamente progettato nell'ambito di GeoMol per poter lavorare sia sugli orizzonti che sulle faglie all'interno di uno spazio 3D



Le faglie sono trattate come insiemi di punti inseriti all'interno del modello di velocità 3D

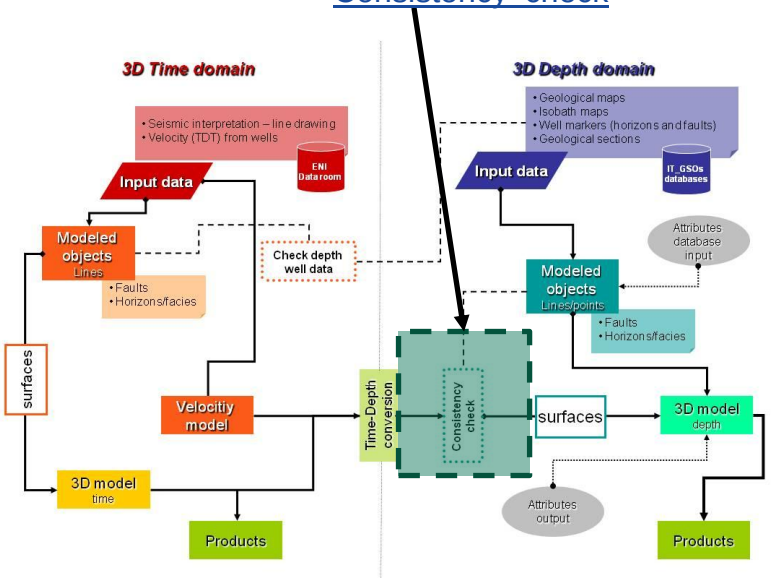
Dopo aver convertito gli orizzonti di riferimento del modello di velocità, i restanti orizzonti e le faglie sono trattati come punti a cui viene assegnato il valore di v0 e k in base alla loro posizione all'interno del modello di velocità

Analisi di consistenza

Dal modello in tempi al modello in profondità

EGU General Assembly
Vienna 12-17 Aprile 2015

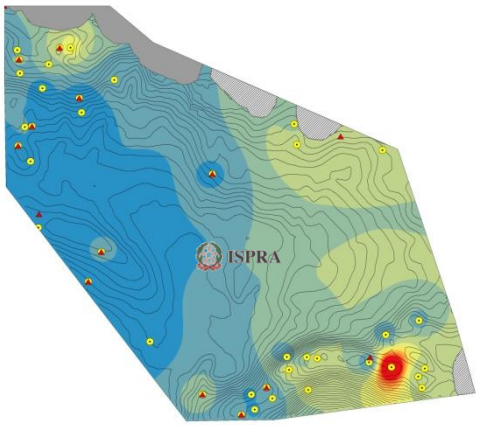
Consistency check

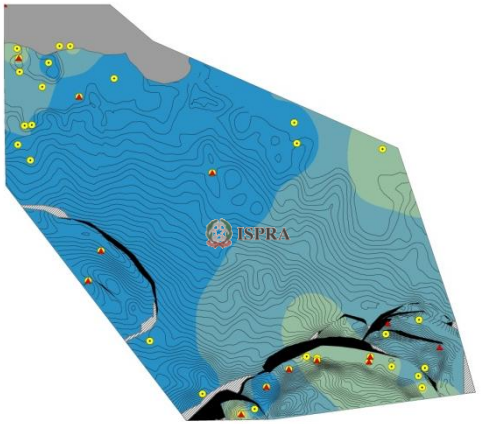


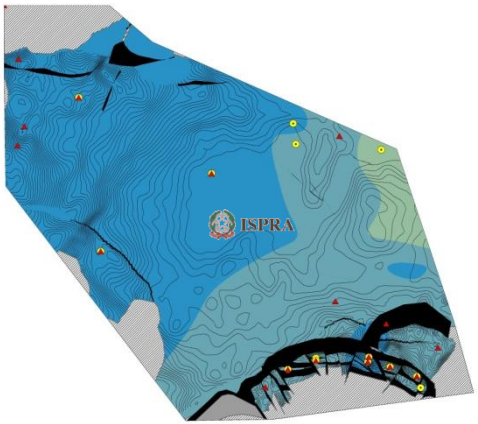
Validazione con i punti di controllo e valutazione delle incertezze

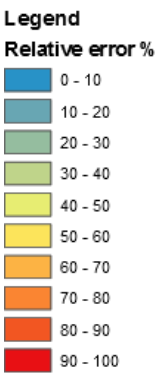
Errore assoluto medio
QM 130 m
PL 150 m
Top Scaglia 250 m

Mappe di incertezza dopo la depth conversion







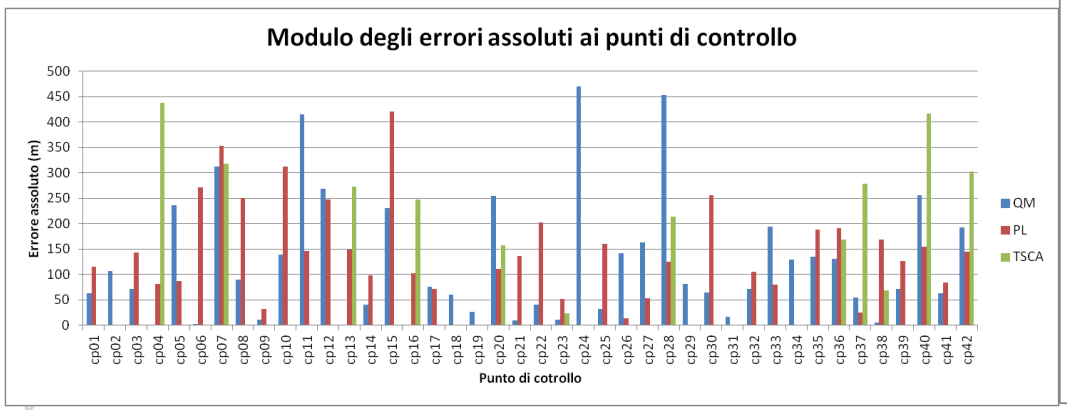


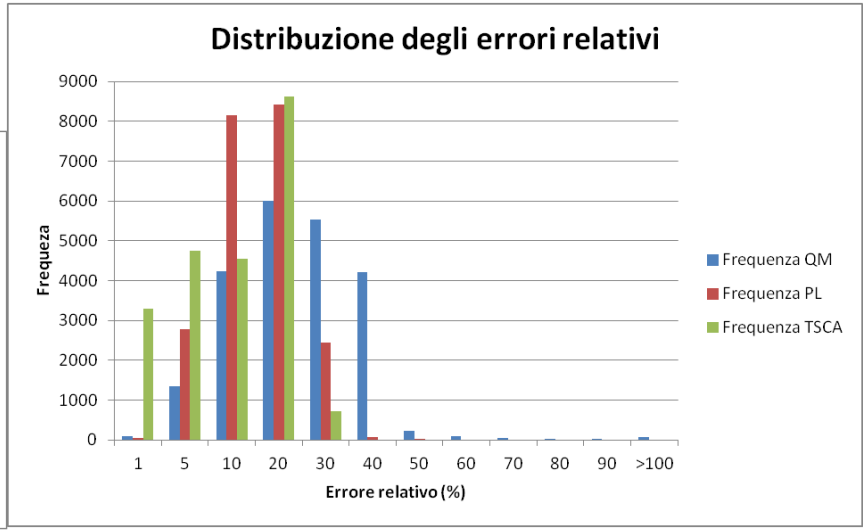
Analisi di consistenza

Dal modello in tempi al modello in profondità

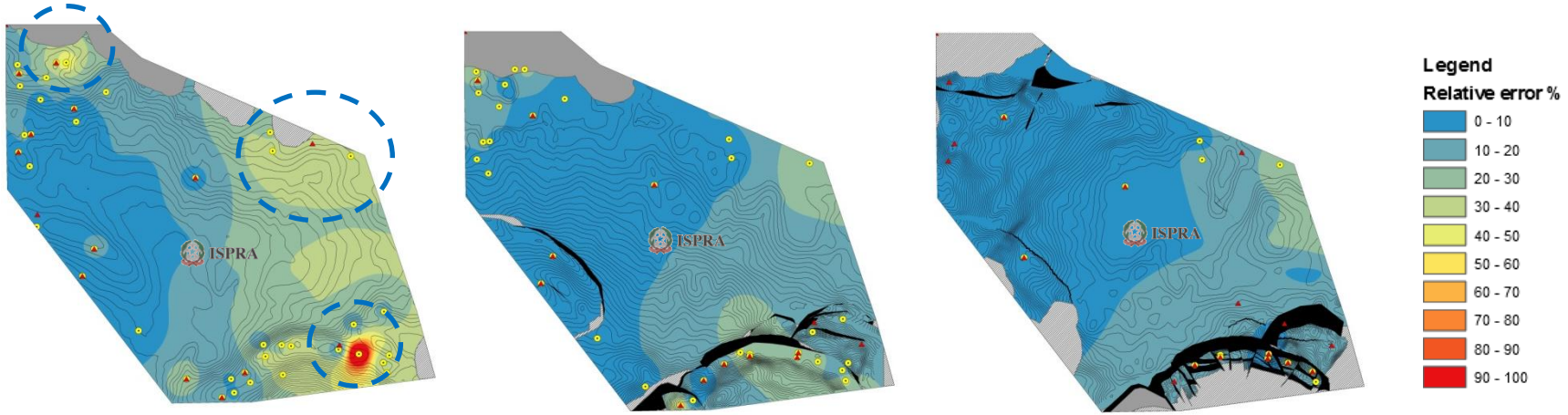
EGU General Assembly
Vienna 12-17 Aprile 2015

Validazione con i punti di controllo e valutazione delle incertezze





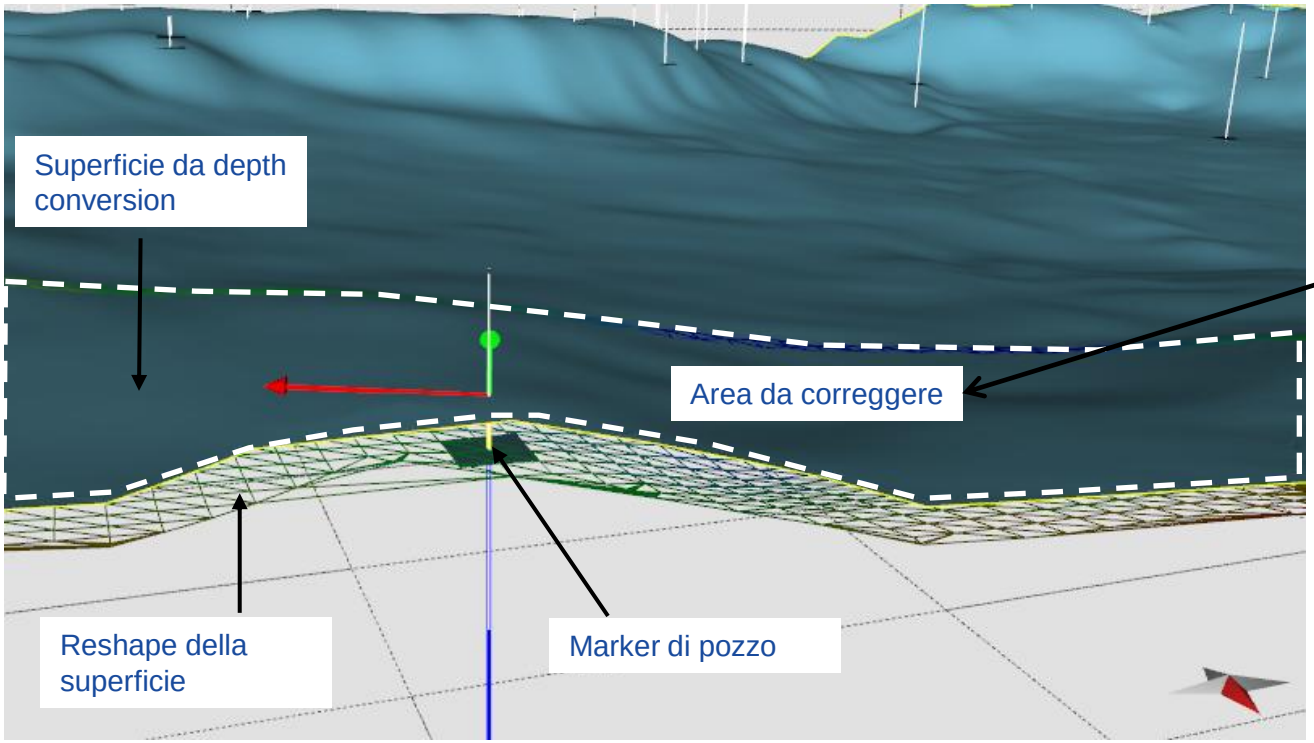
Mappe di incertezza dopo la depth conversion

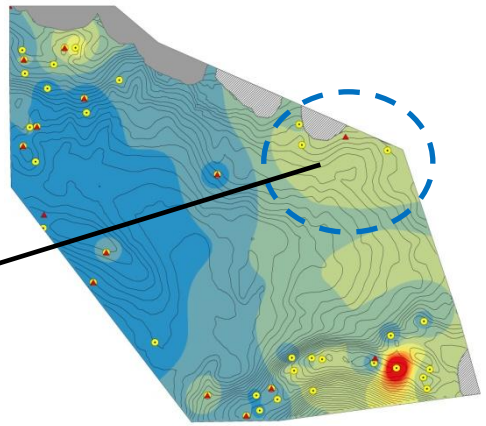


Raffinamento delle superfici

Editing delle superfici in profondità

Correzione delle anomalie dovute alla non omogenea distribuzione dei dati di velocità

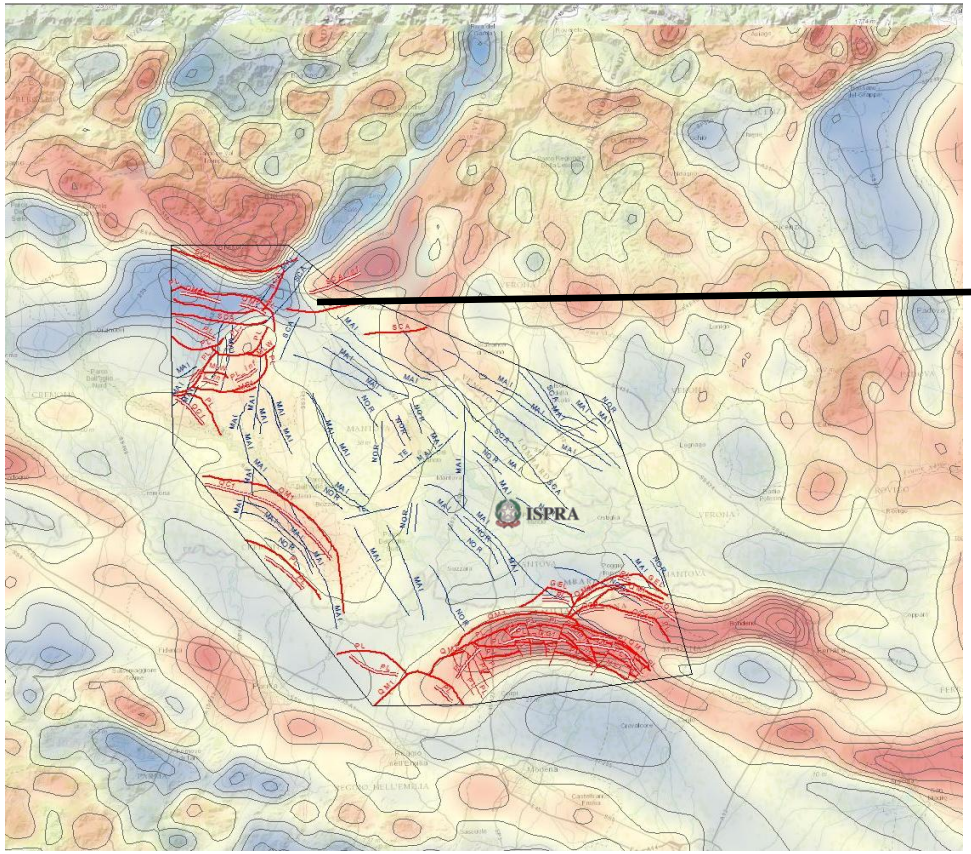


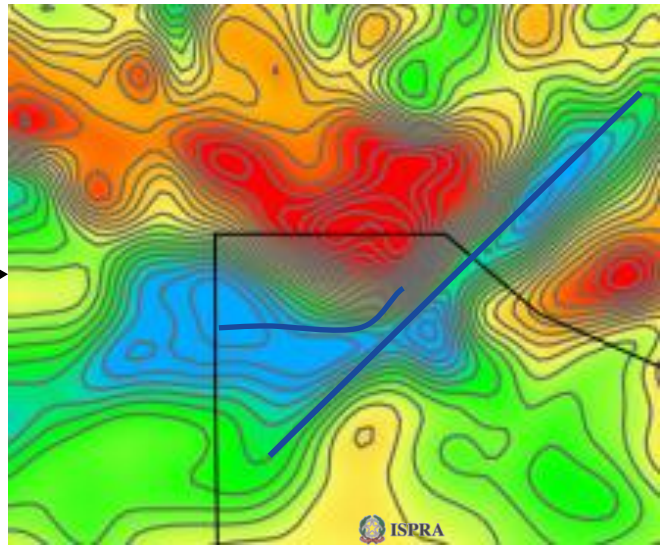


Raffinamento delle superfici

Interpretazione strutturale integrata con elaborazioni indipendenti

Filtraggio ed analisi delle anomalie gravimetriche





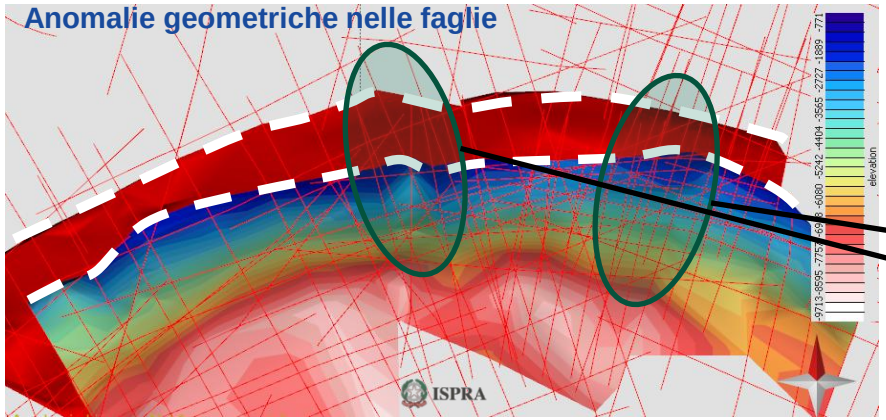
Supporto della gravimetria per l'interpretazione di aree problematiche

Dataset ENI, Elaborazioni ISPRA – F. Ferri

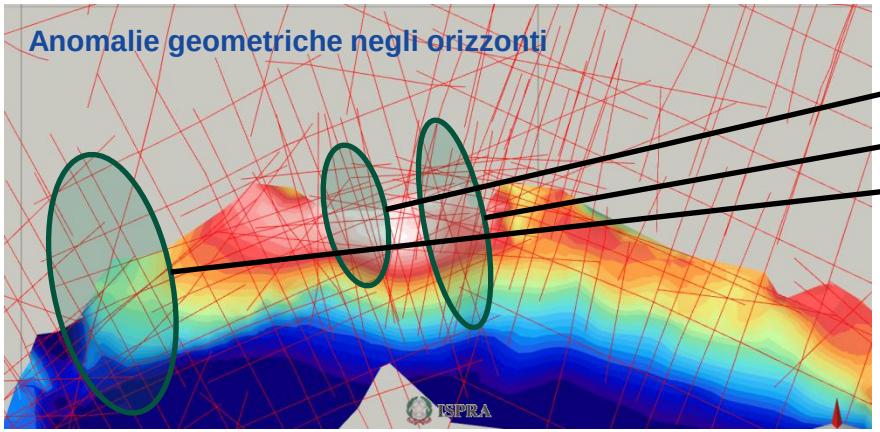
Raffinamento delle superfici

Editing delle faglie

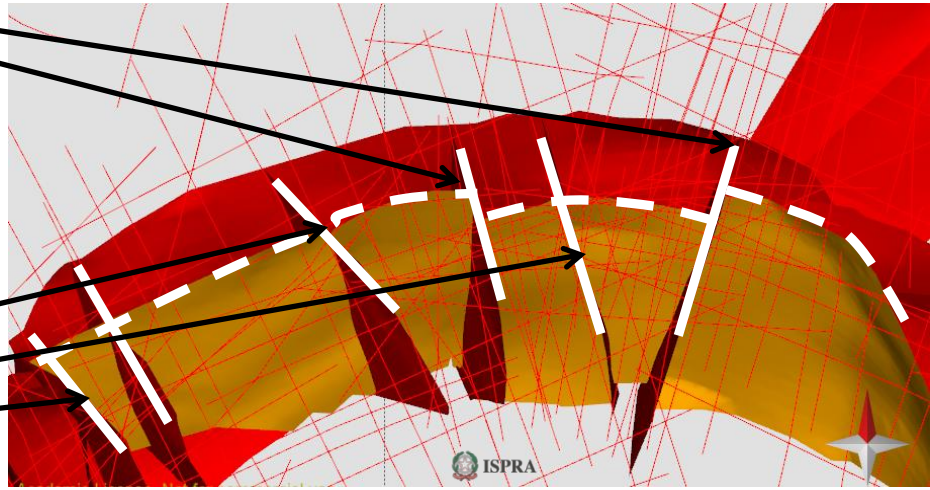
Anomalie geometriche nelle faglie



Anomalie geometriche negli orizzonti



Segmentazione degli elementi strutturali



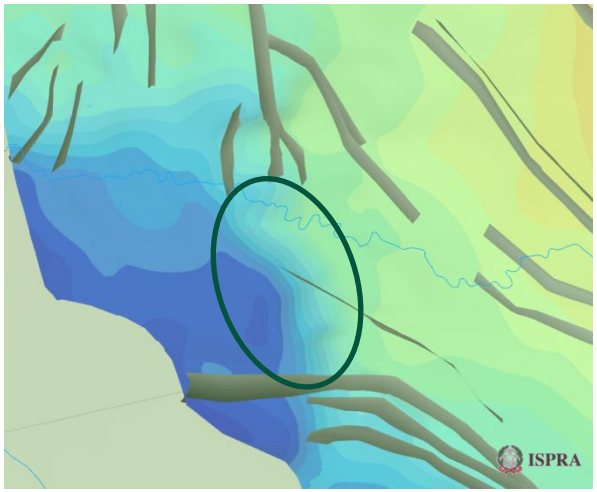
Raffinamento delle superfici

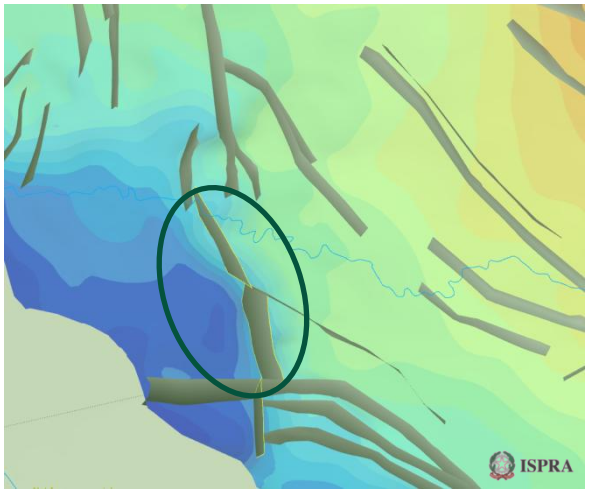
Editing delle faglie

La definizione della continuità laterale dipende dalla spaziatura delle linee sismiche e dalla loro orientazione prevalente.

L'errata correlazione è facilmente identificata una volta costruito il modello 3D preliminare.

L'uso dei modelli 3D permette di identificare discontinuità anche in aree con carenza di dati.





Il modello 3D

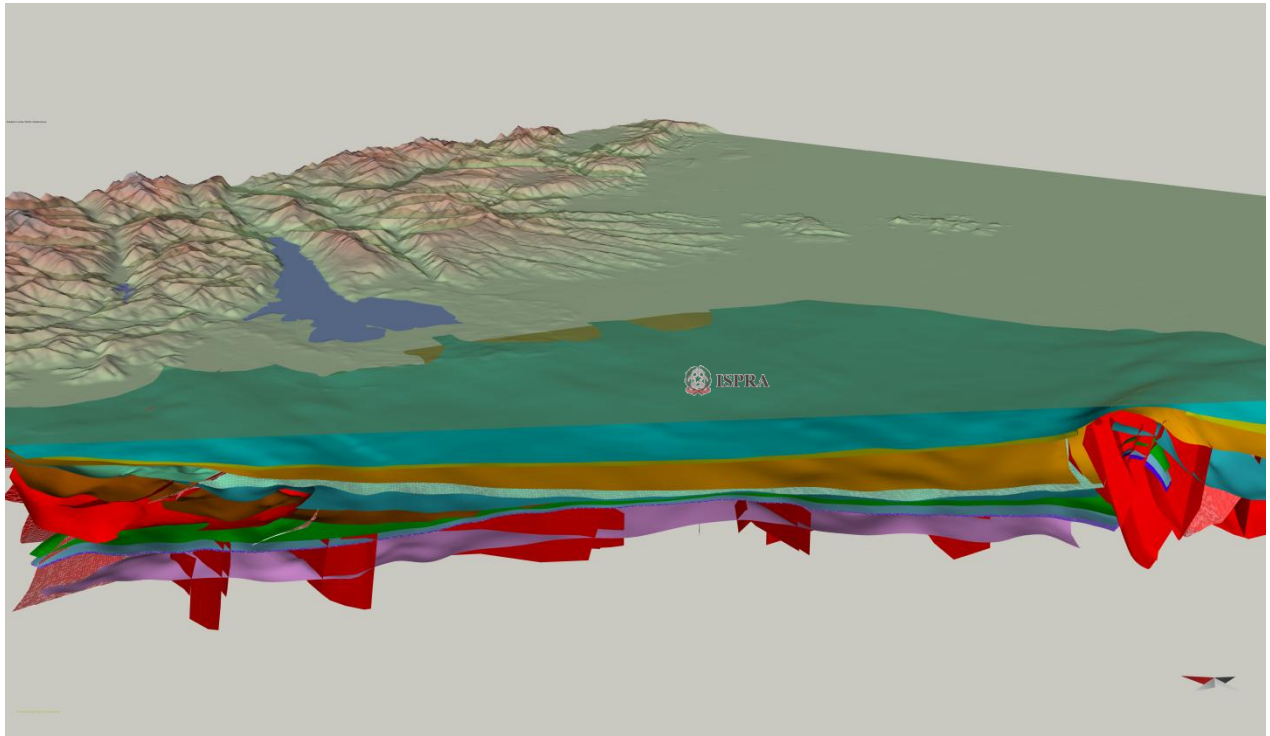
Caratteristiche

Orizzonti modellati: 15

Con dettaglio nel Pleistocene: 7 orizzonti dal Gelasiano al Pleistocene medio

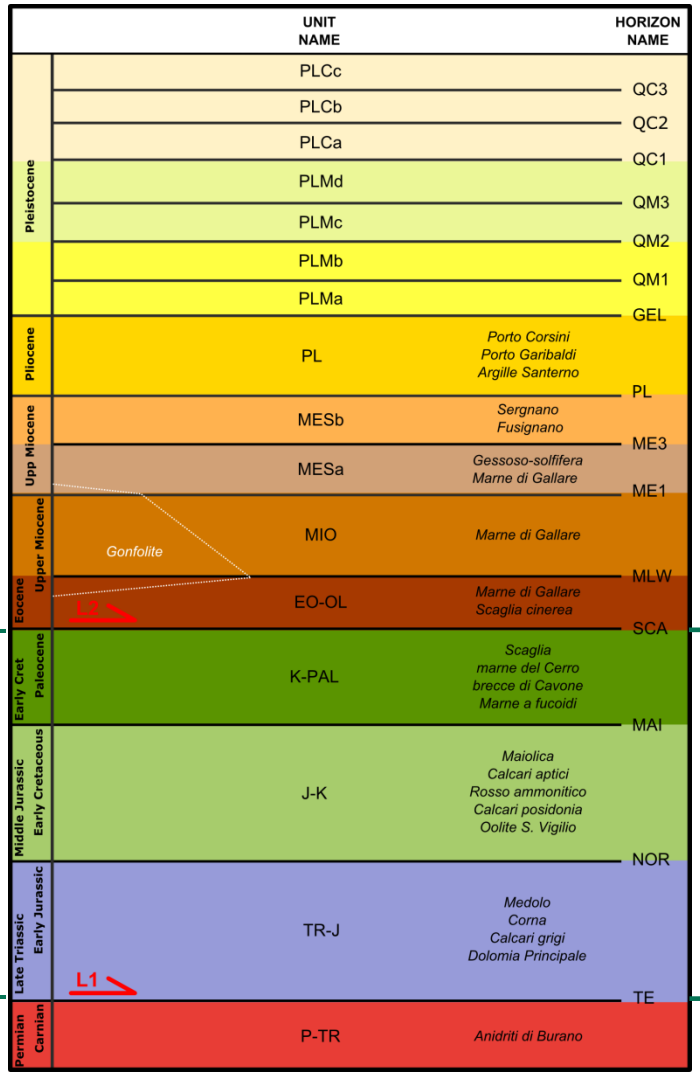
Faglie modellate: 132

Risoluzione orizzontale: 500x500 m



Il modello 3D

Schema Stratigrafico



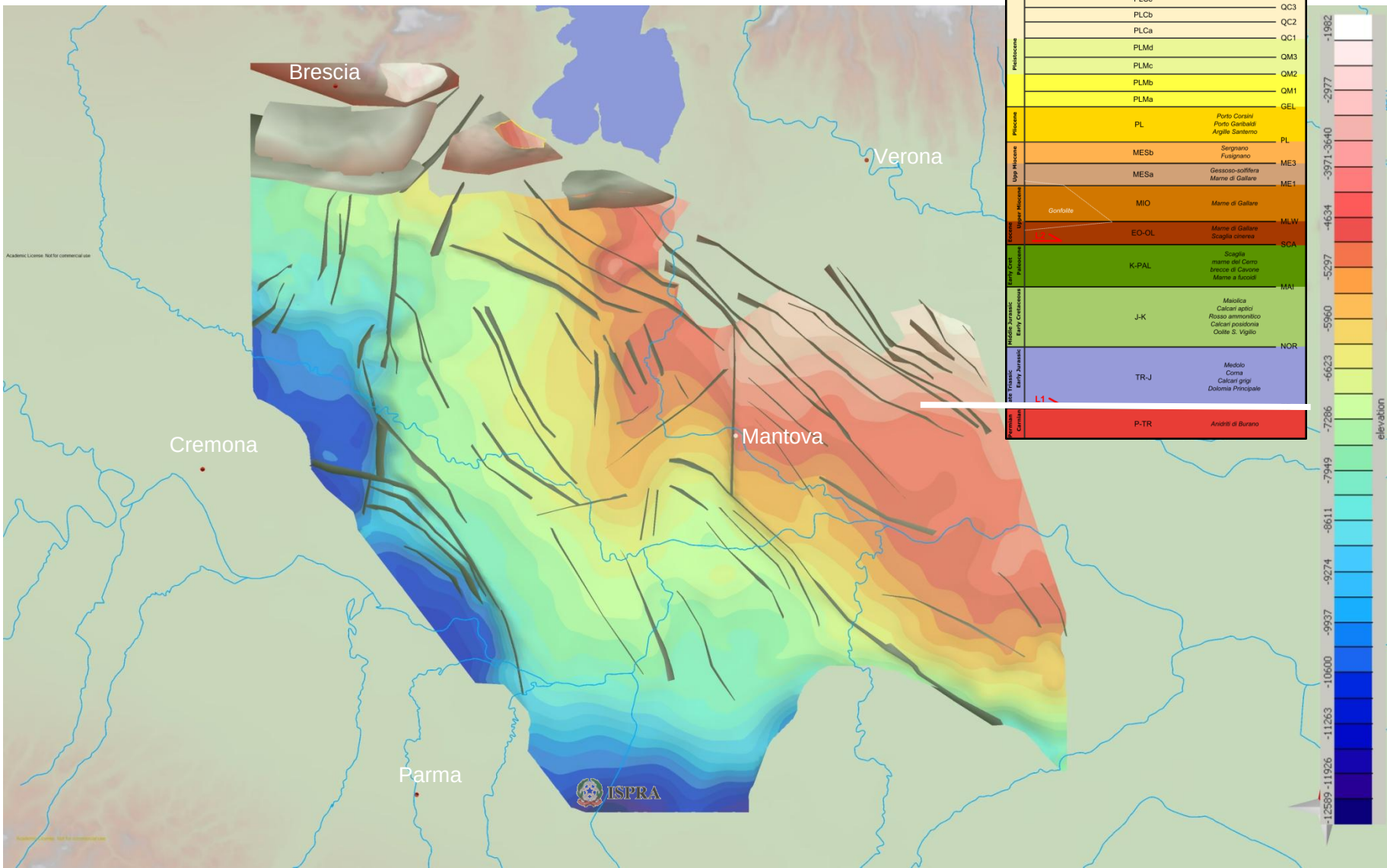
11 unconformity

4 Top

Livello di scollamento nella successione Oligo-Miocenica

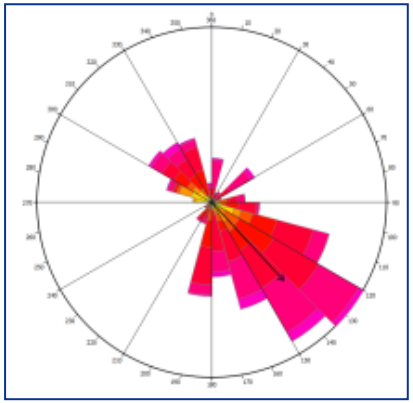
Livello di scollamento al top delle evaporiti triassiche

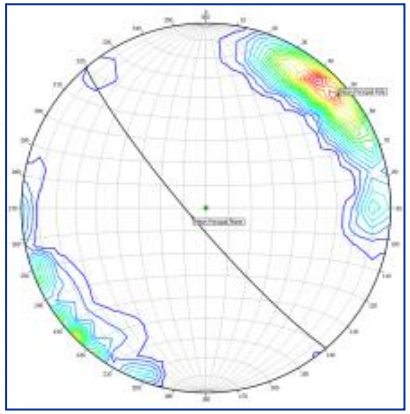
Top Evaporiti Triassiche



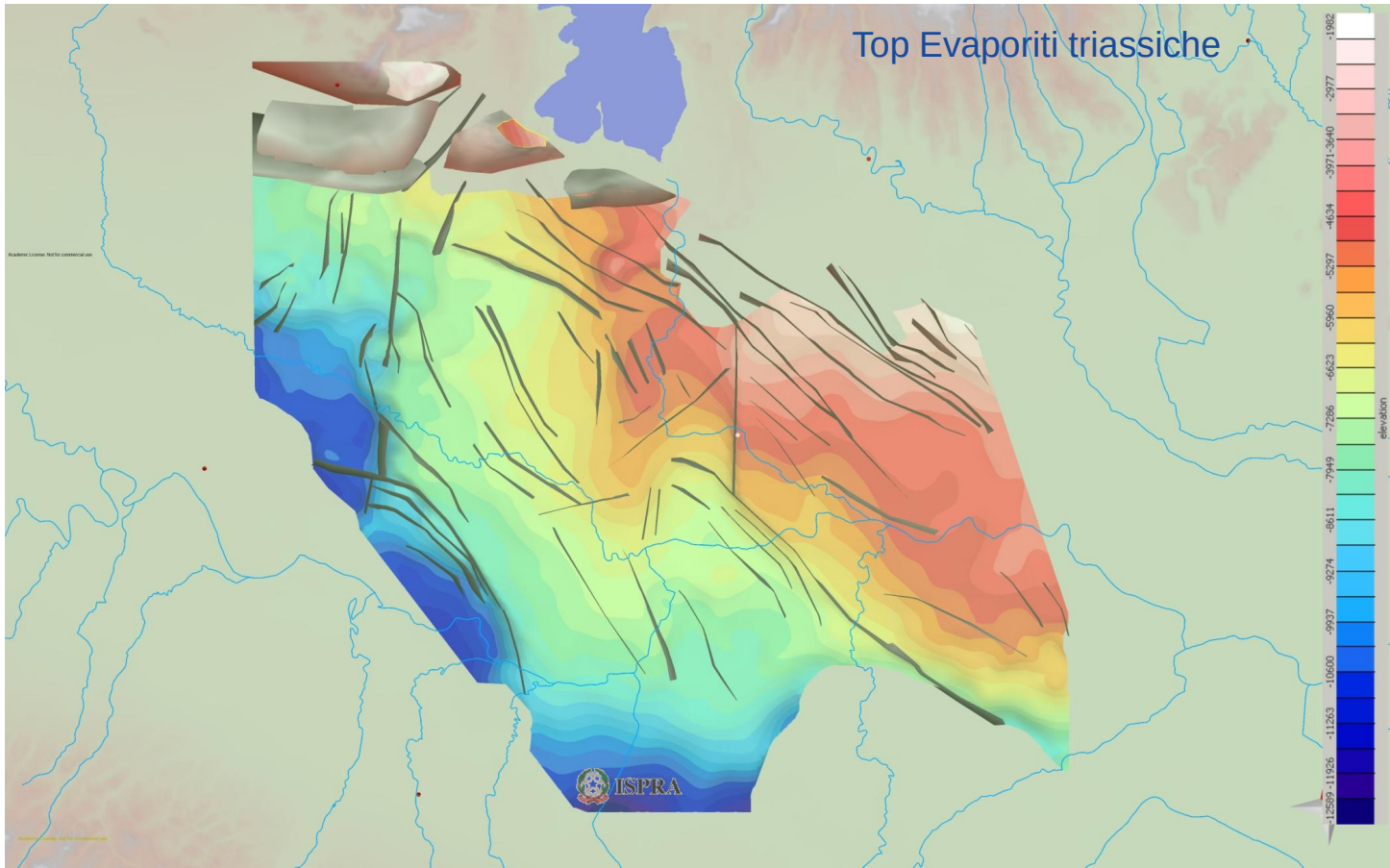
Analisi strutturale: faglie dirette mesozoiche

Faglie dirette

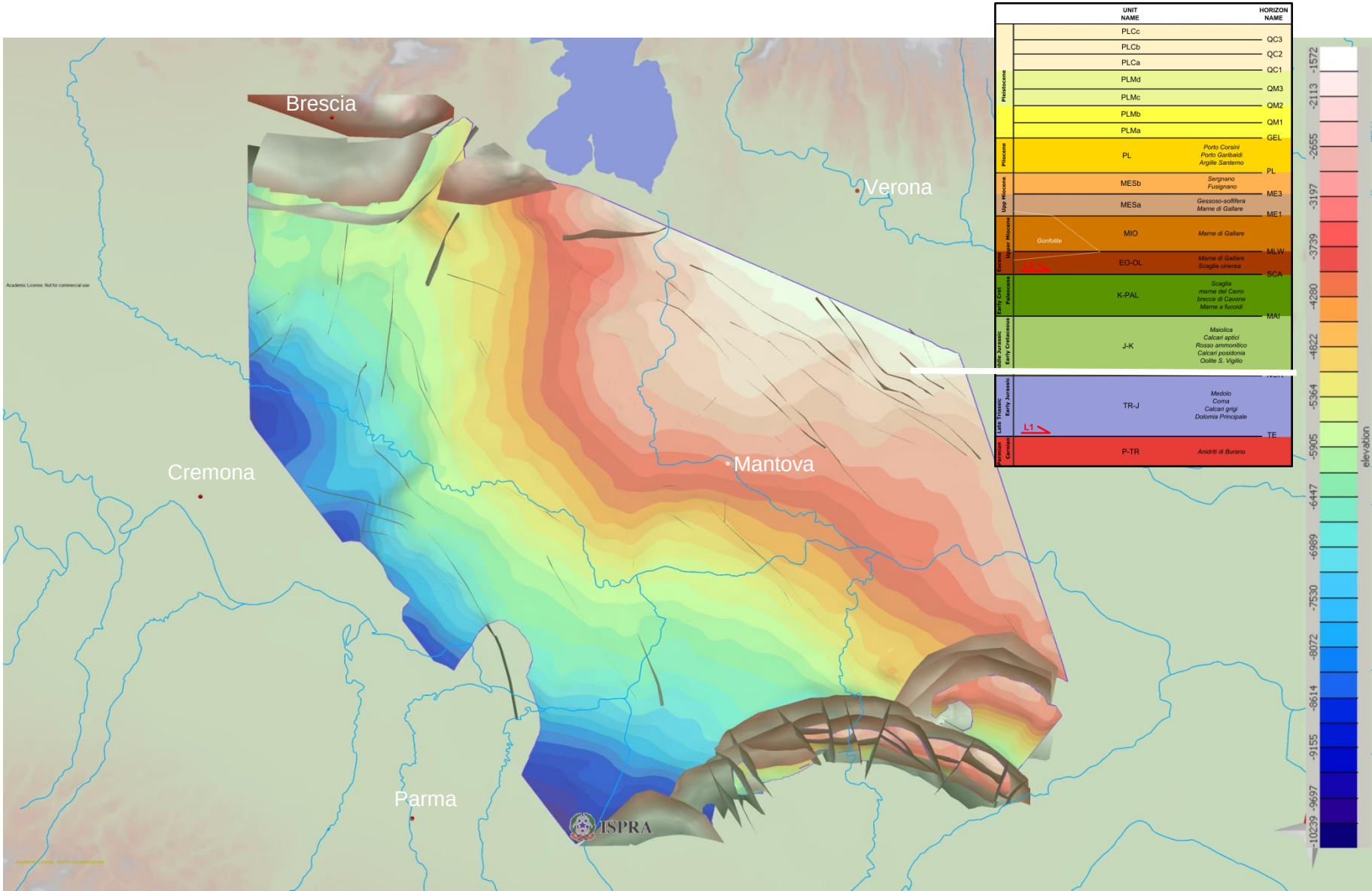




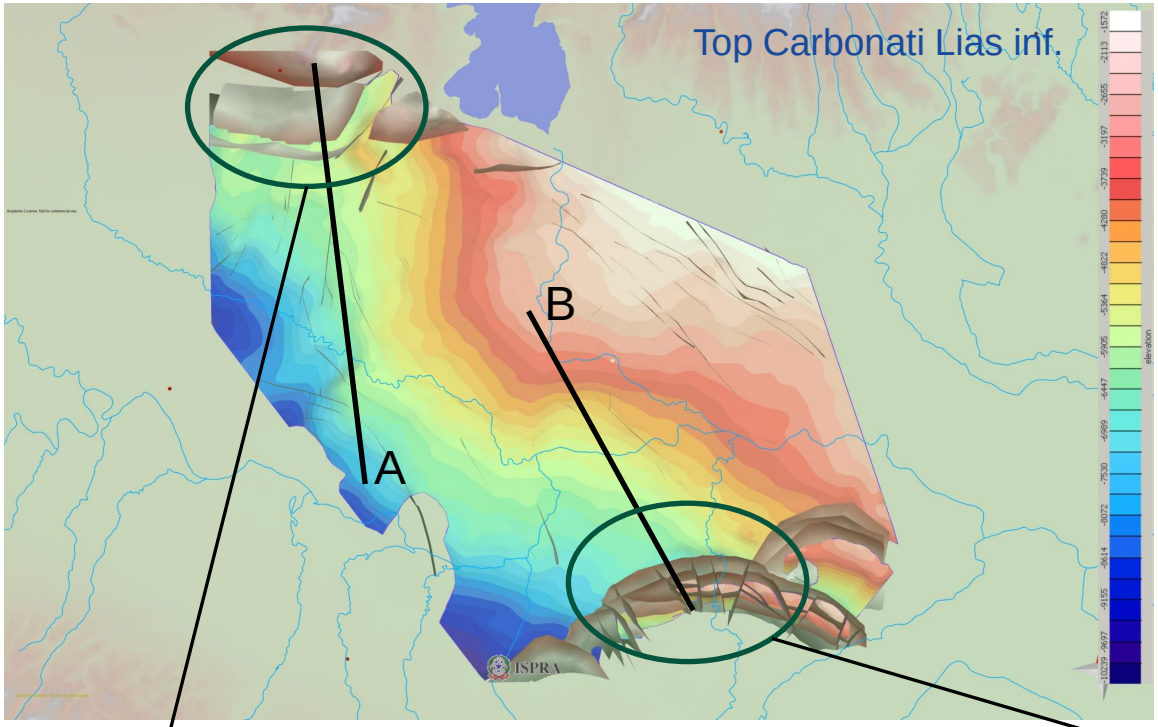
Output verso analisi sismotettonica

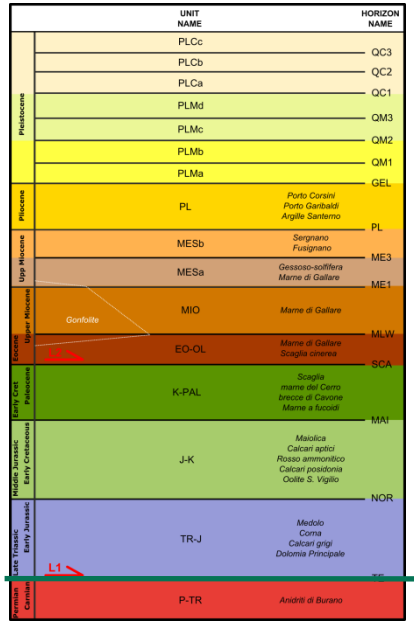


Top Carbonati Lias inf.

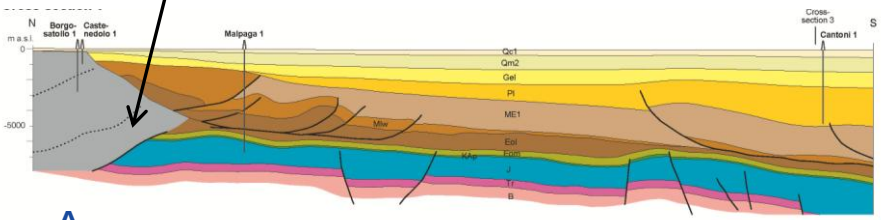


Strutture compressive: livello di scollamento profondo

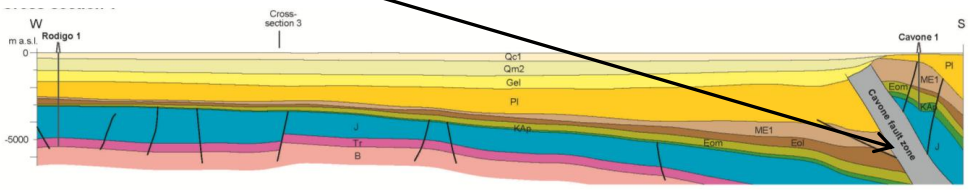




L1



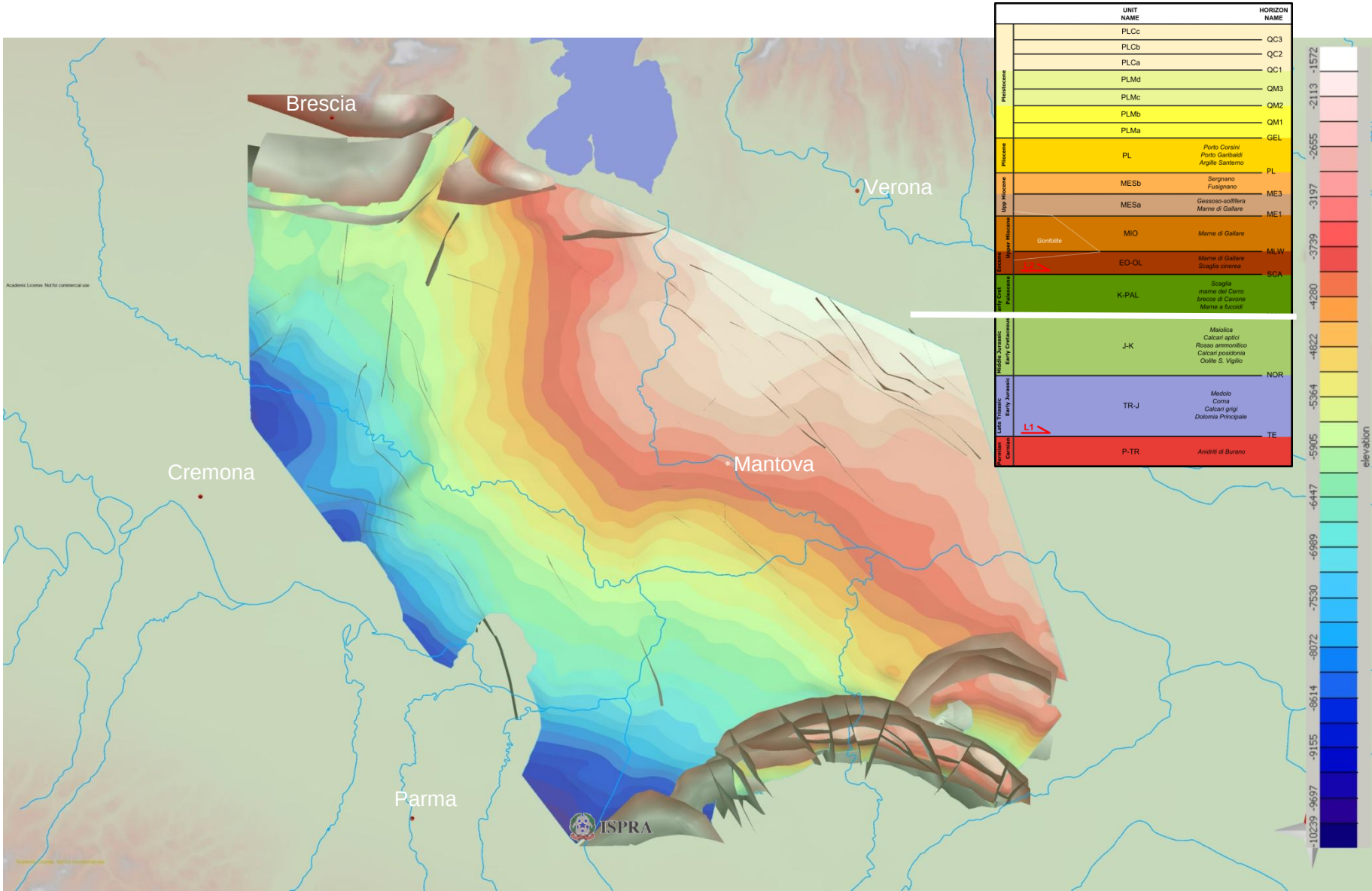
A



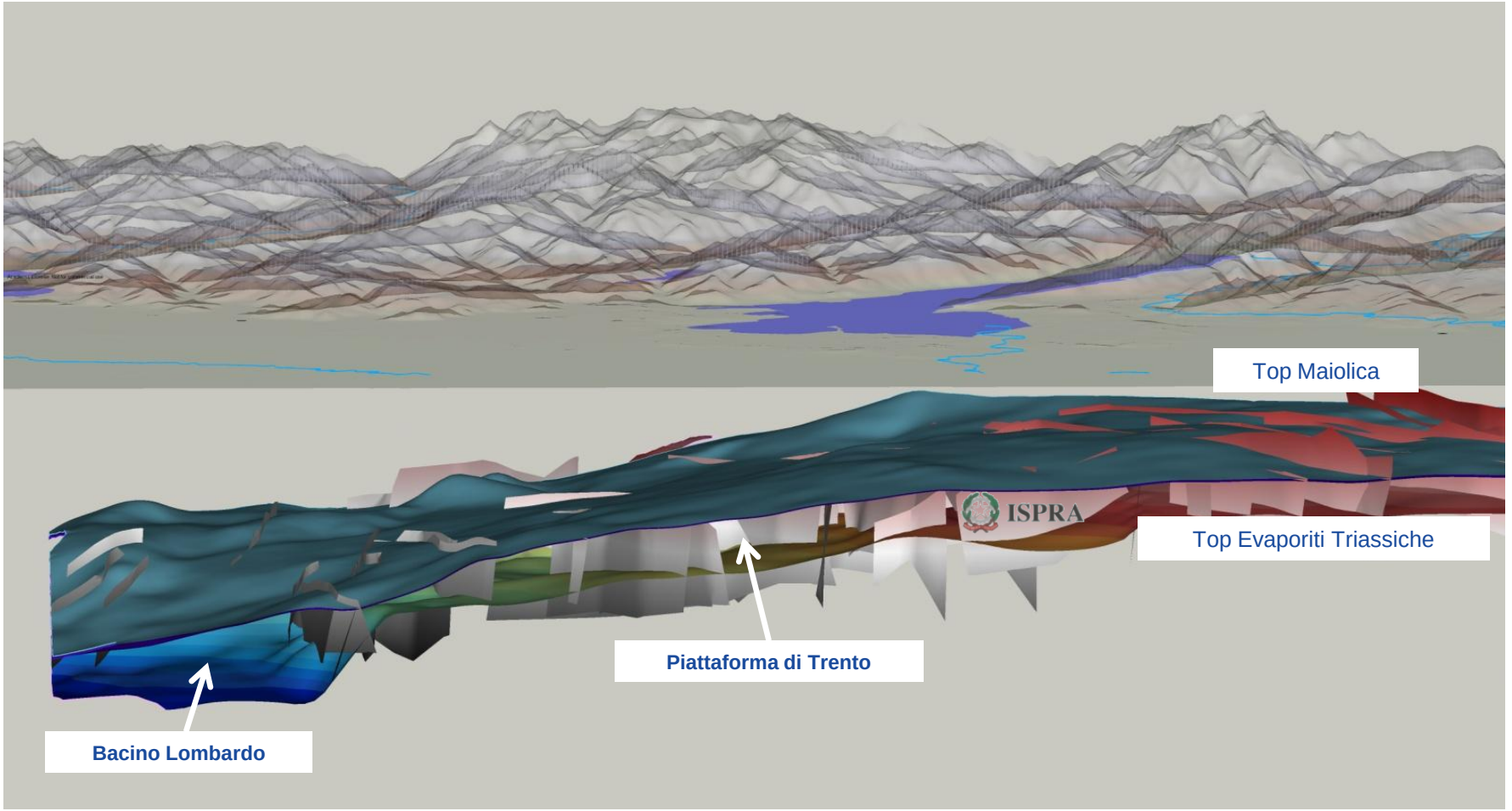
B

I thrust che coinvolgono i carbonati hanno caratteristiche diverse: thick skinned (taglia le evaporiti triassiche) nella catena Sud Alpina e thin skinned (scolla al tetto delle evaporiti triassiche) nel fronte esterno dell'Appennino Settetrionale.

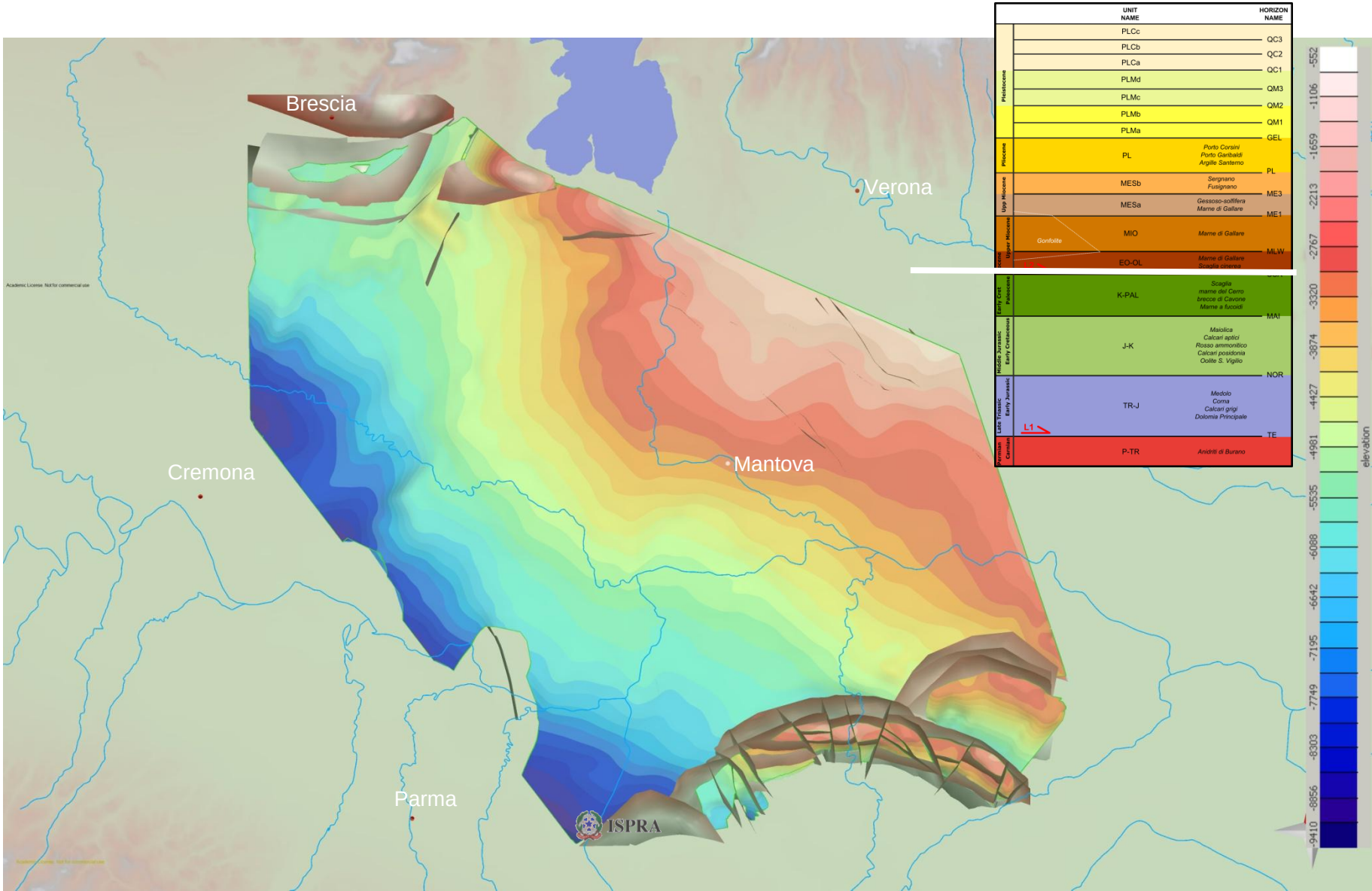
Top Maiolica (Cretaceo inferiore)



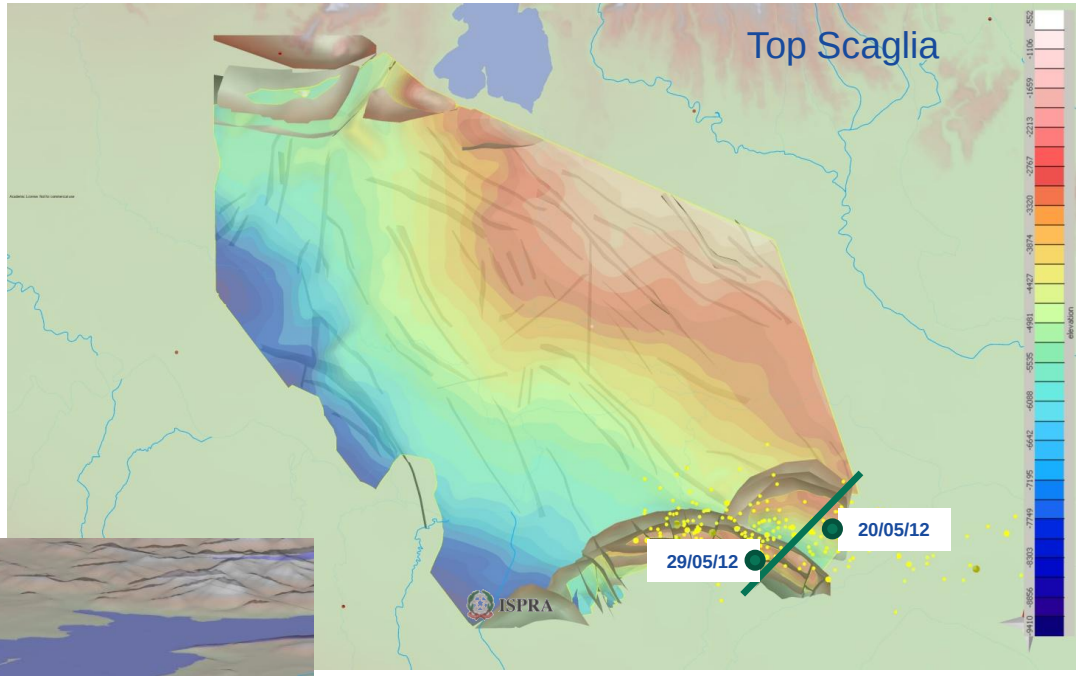
Paleogeografia: transizione piattaforma-bacino

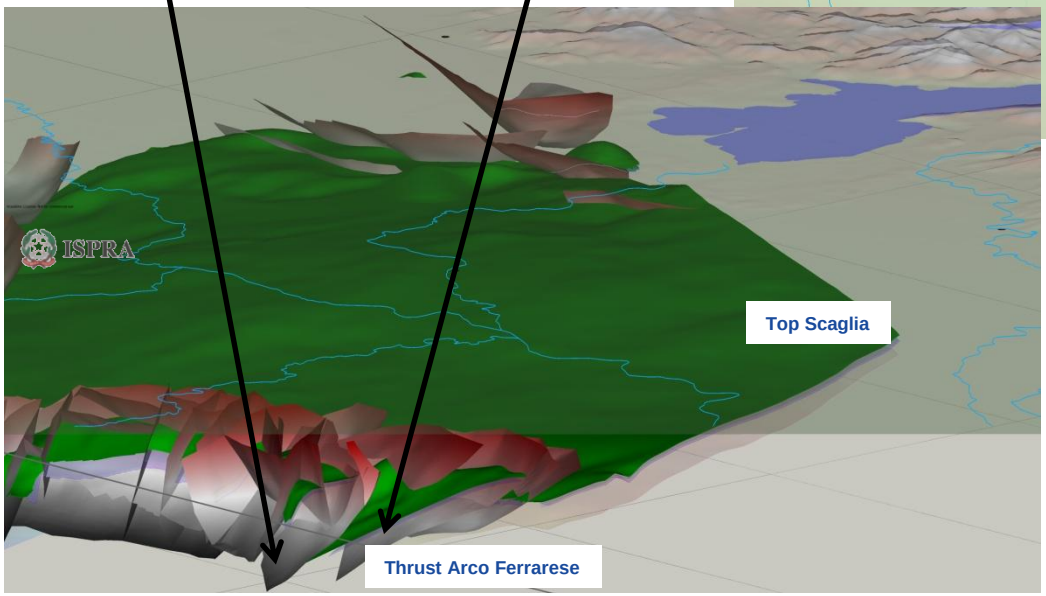


Top Scaglia

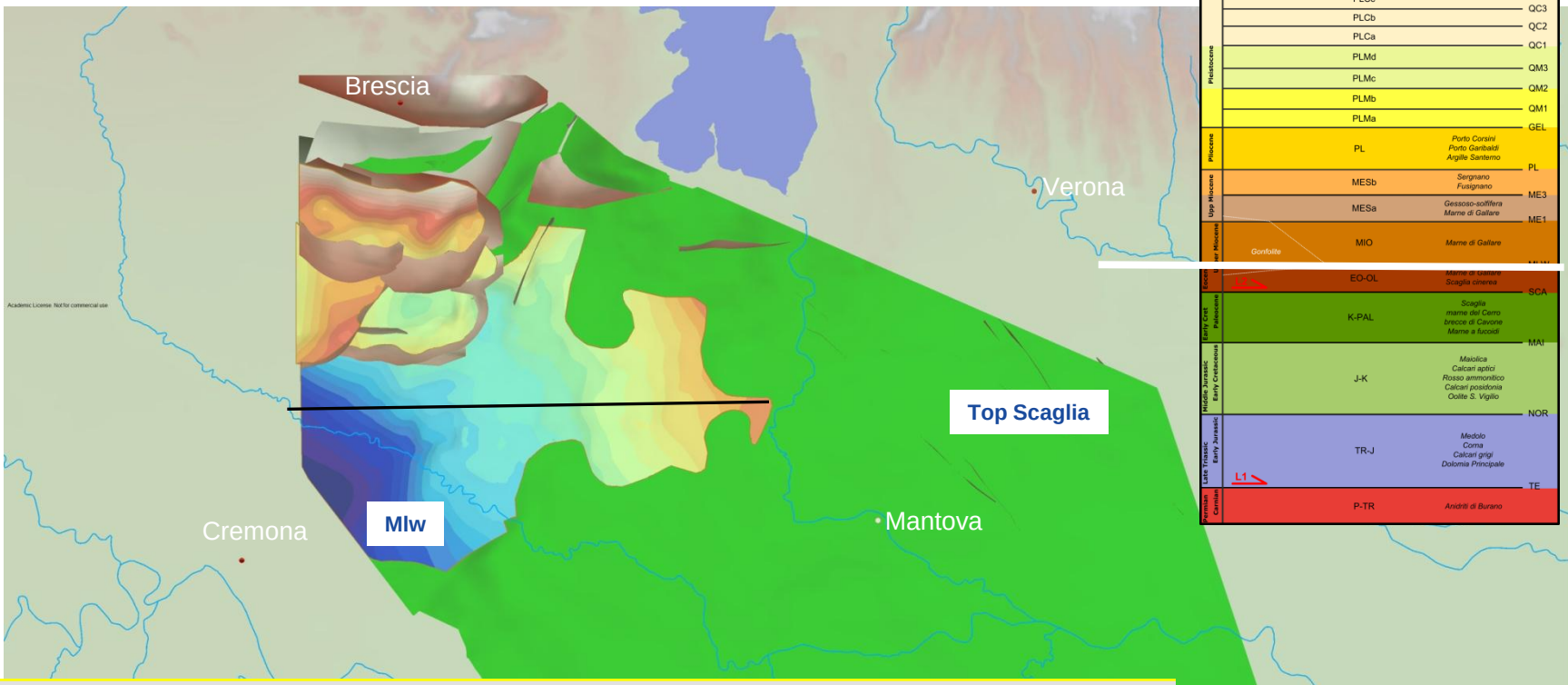


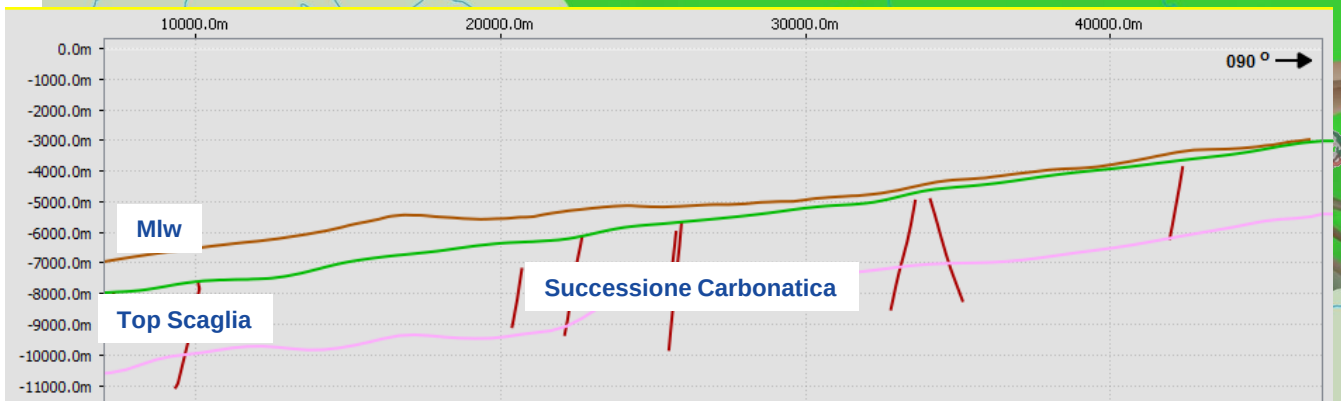
Caratterizzazione 3D delle strutture interessate dalla sequenza sismica del 2012



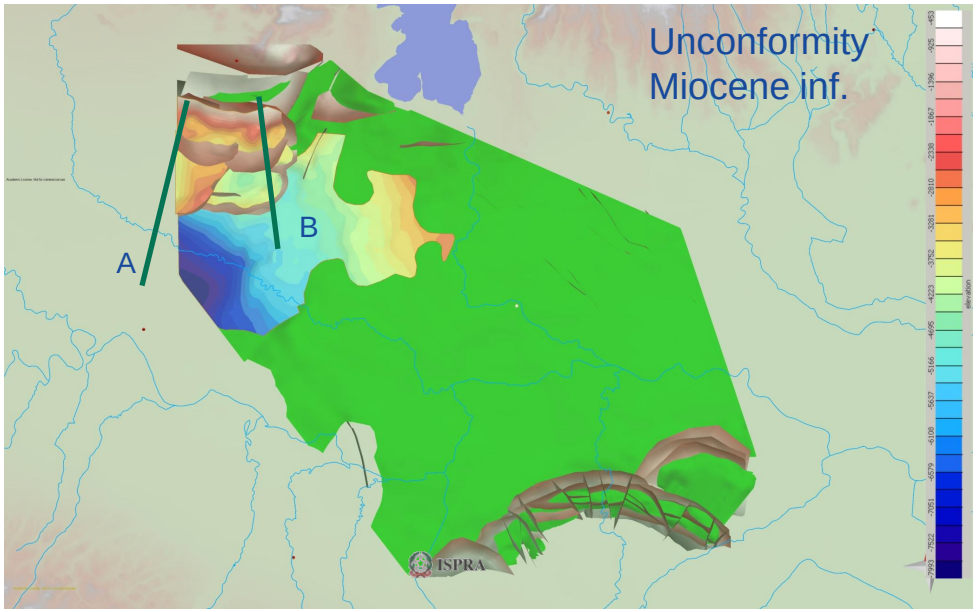


Unconformity Miocene inferiore

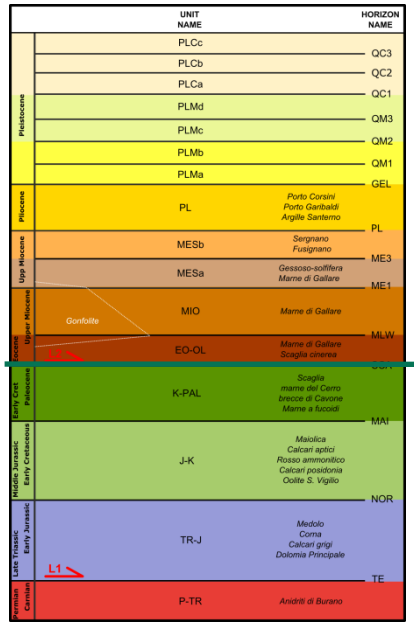




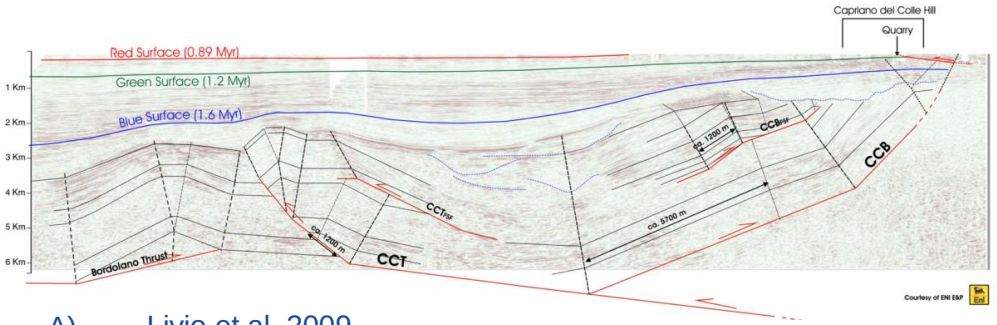
Livello di scollamento superficiale nell'avanfossa Sudalpina



SSW NNE

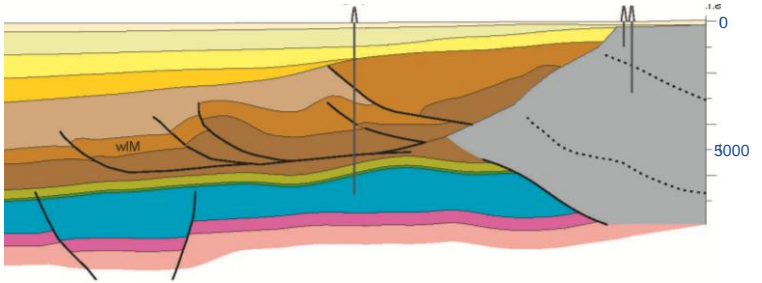


L2



A) Livio et al. 2009

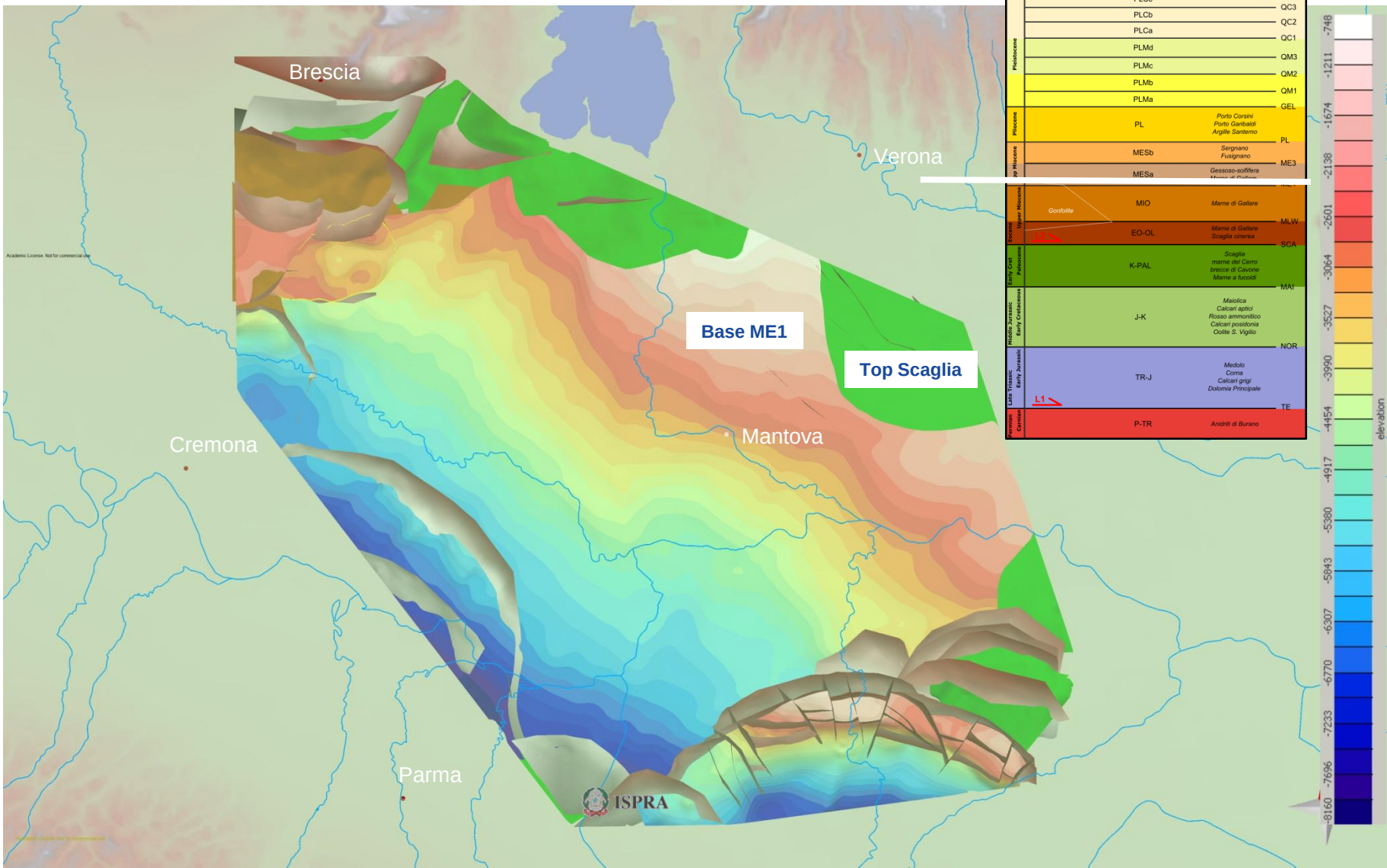
S N



B) GeoMol final report

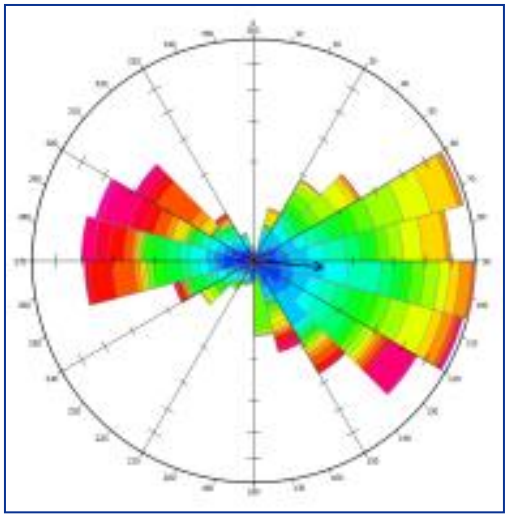
Output verso analisi sismotettonica

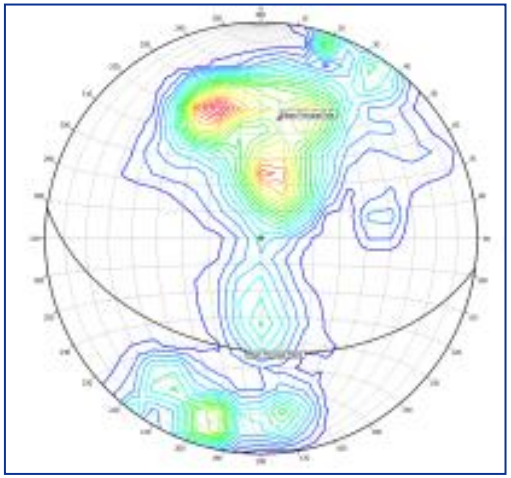
Unconformity Tortoniano superiore
Base ME1



Analisi strutturale: strutture compressive sudalpine ed appenniniche

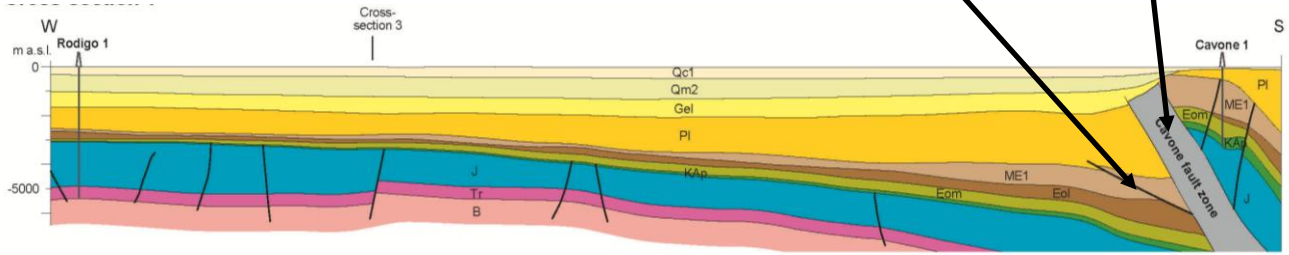
Thrust

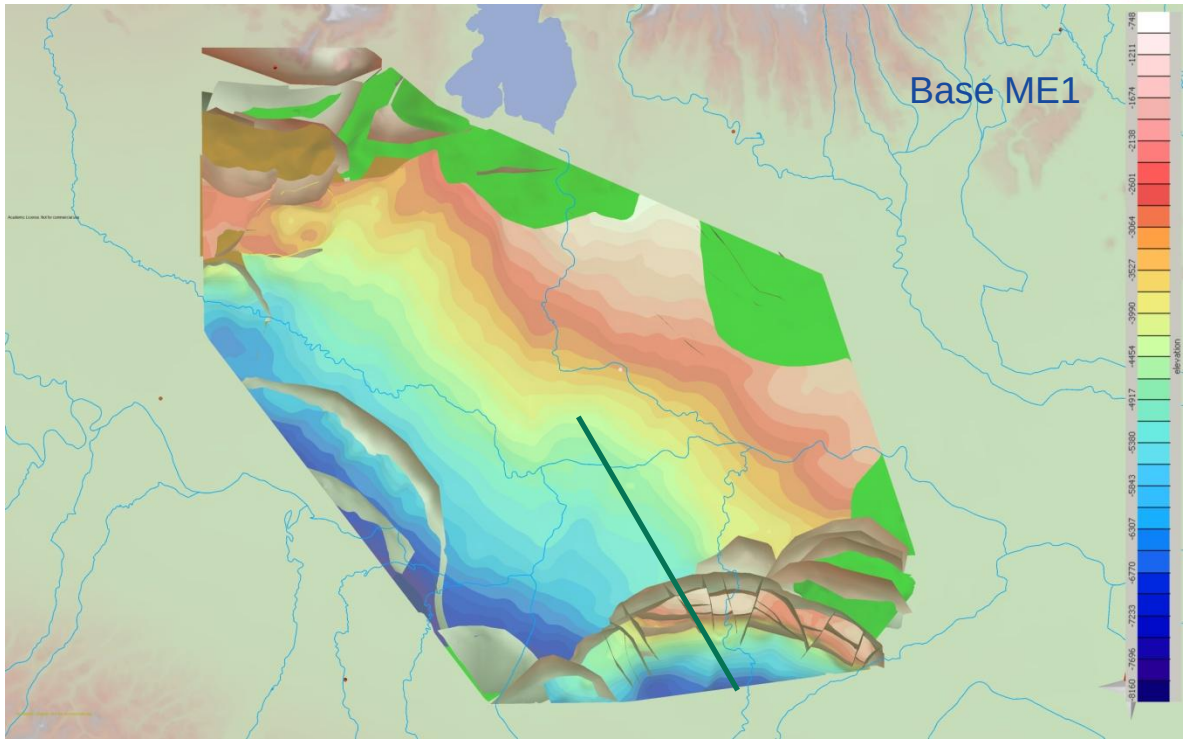




Thrust L1

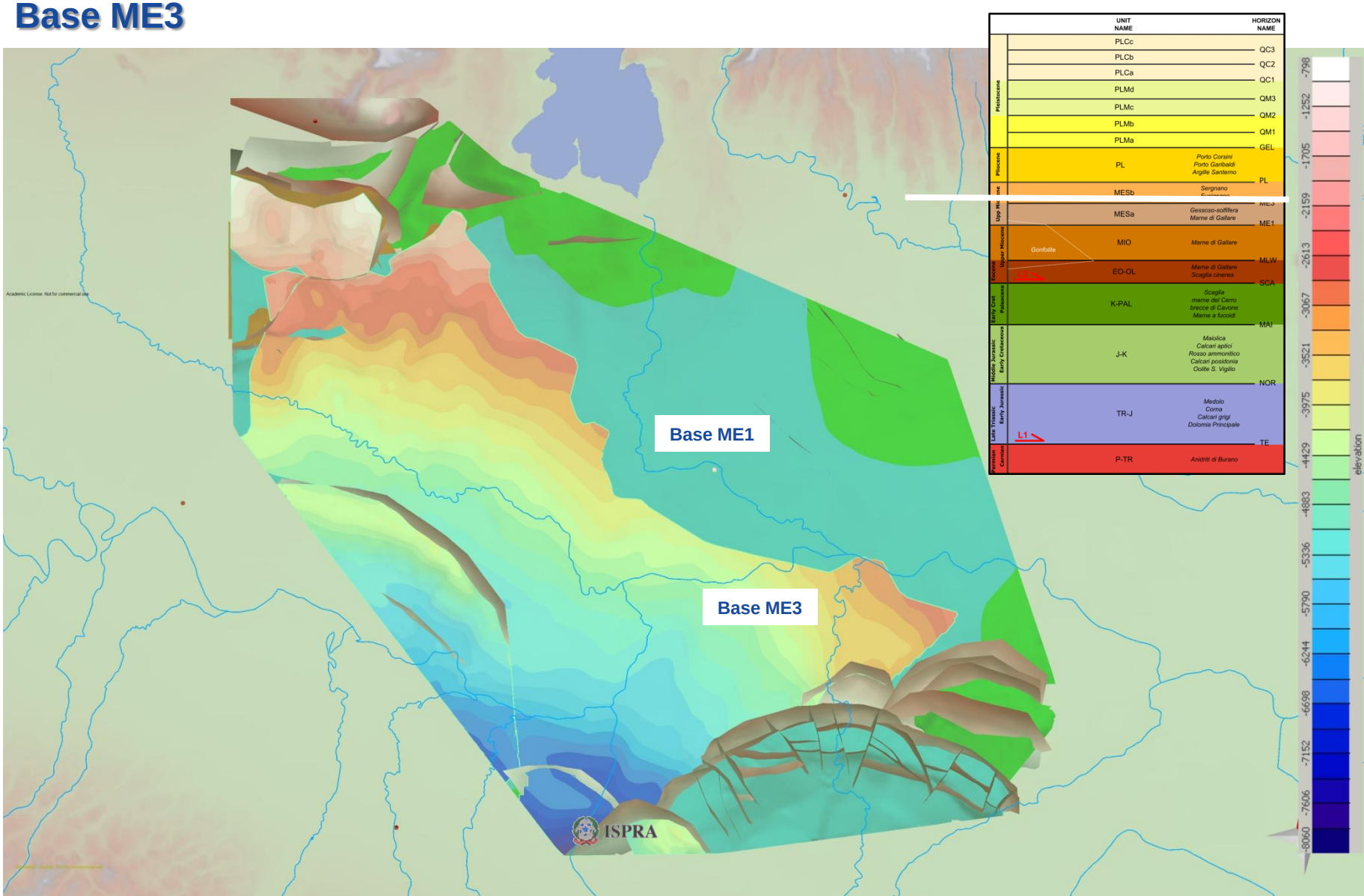
Thrust L2



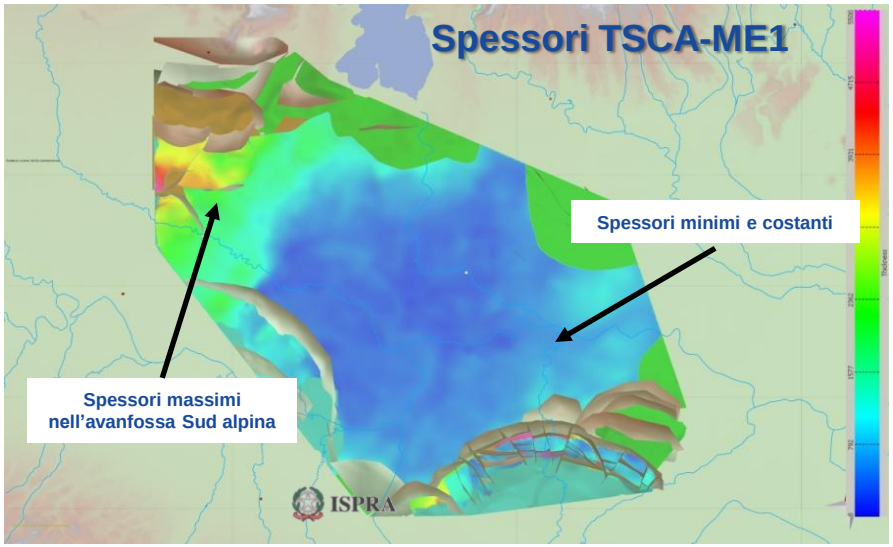


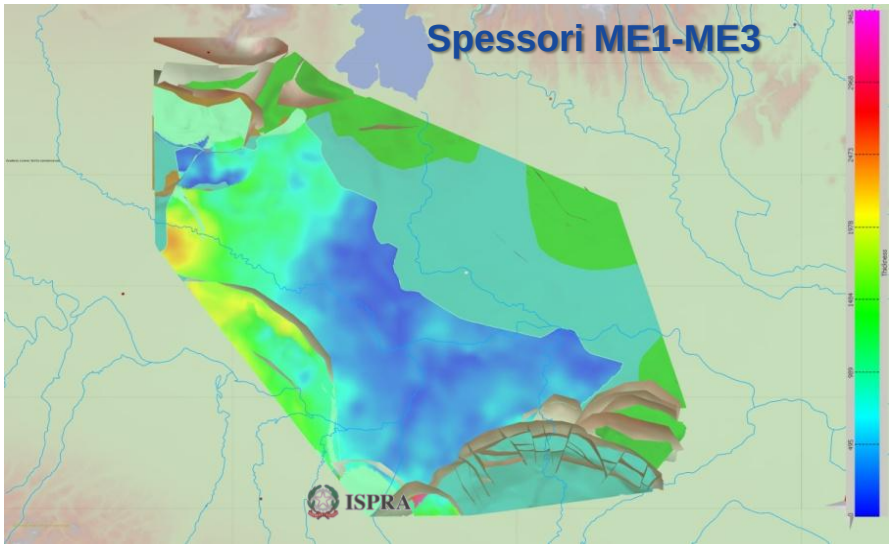
Output verso analisi sismotettonica

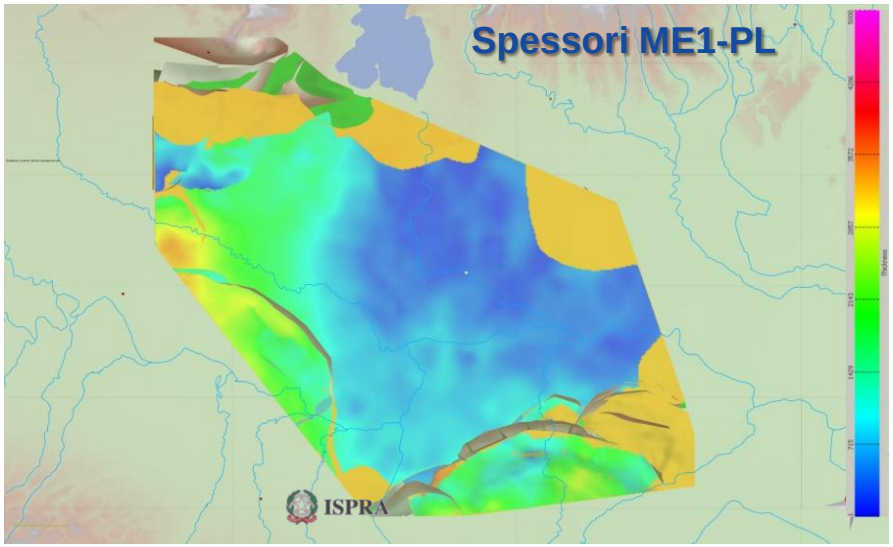
Unconformity intra-messiniana
Base ME3

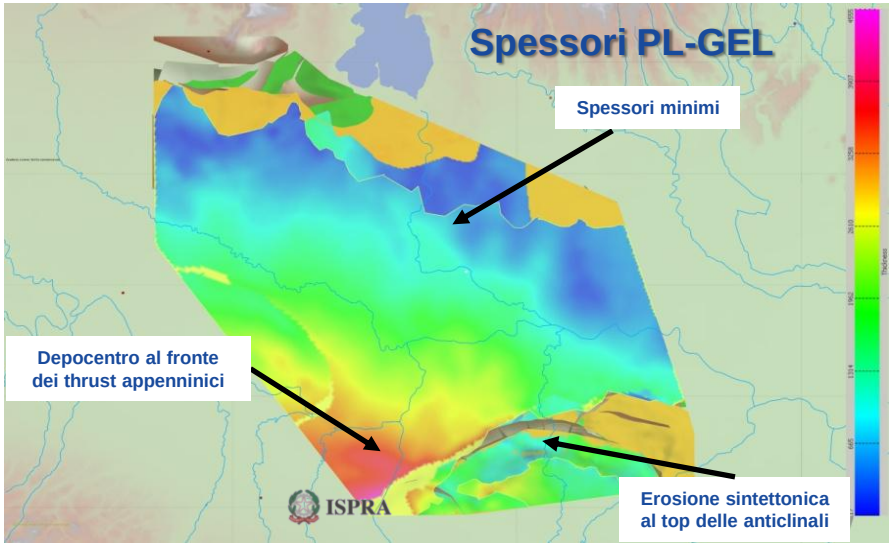


Evoluzione delle avanfosse

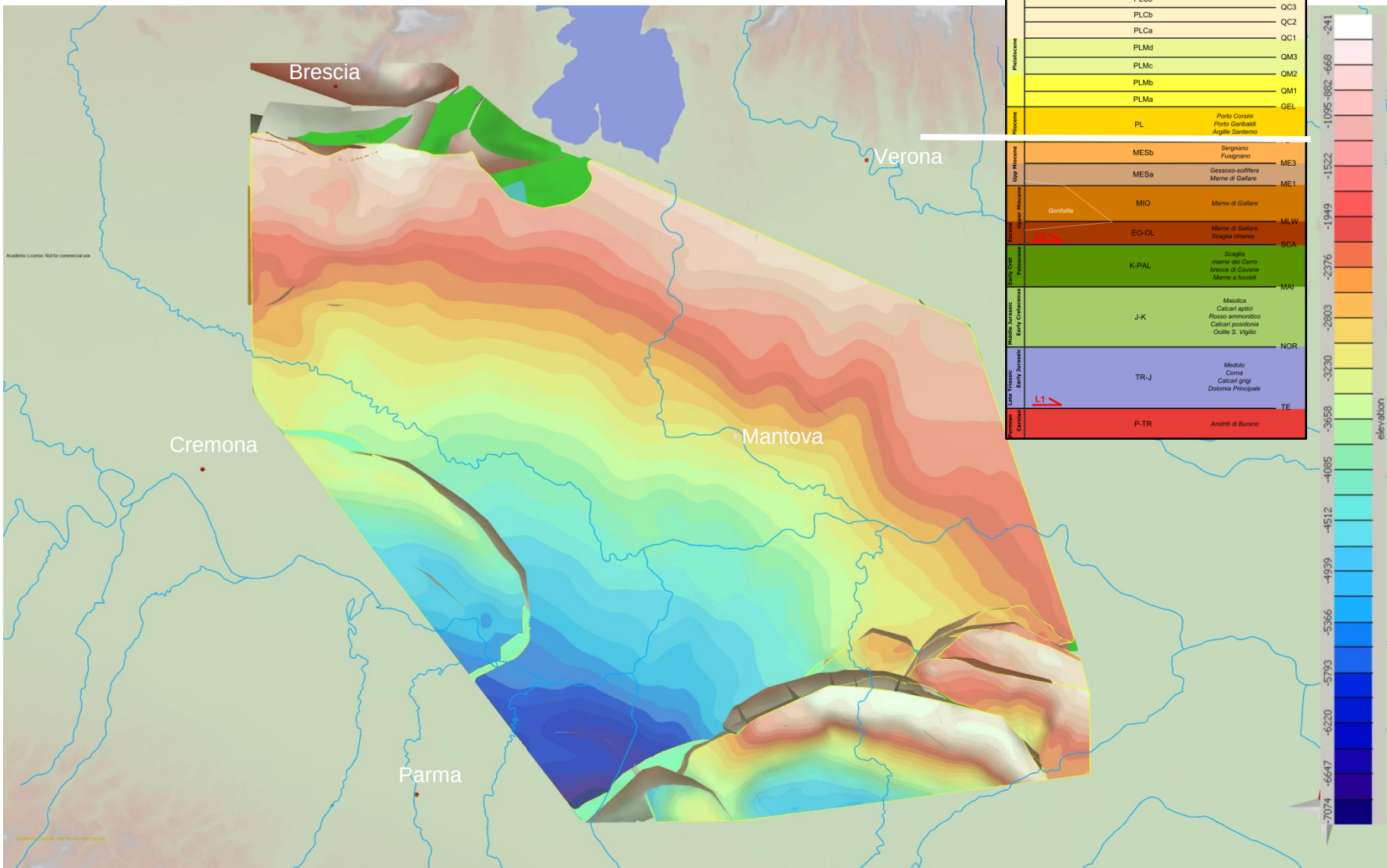






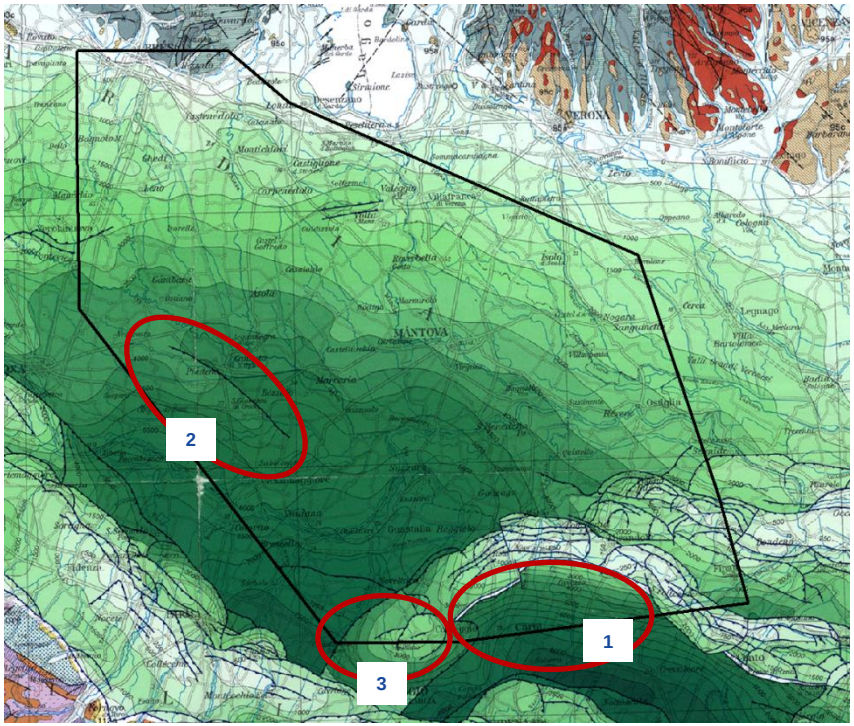


Unconformity intra-zancleana
Base PL

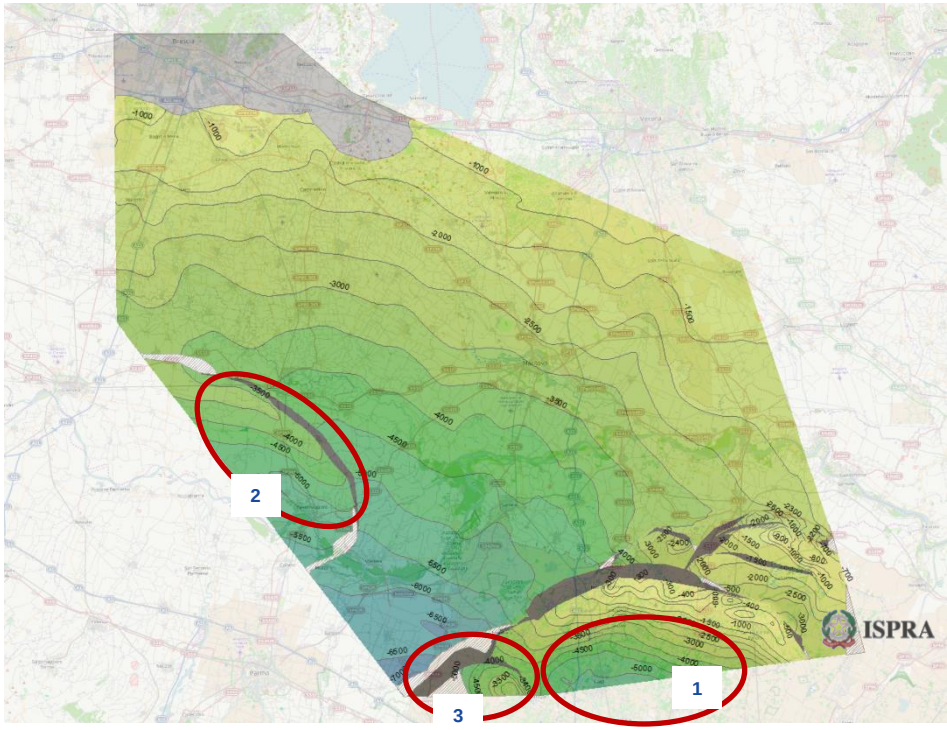


Miglioramento delle conoscenze

Base Pliocene, da Modello Strutturale



Unconformity intra-zancleana – Base Pliocene da modello GeoMol

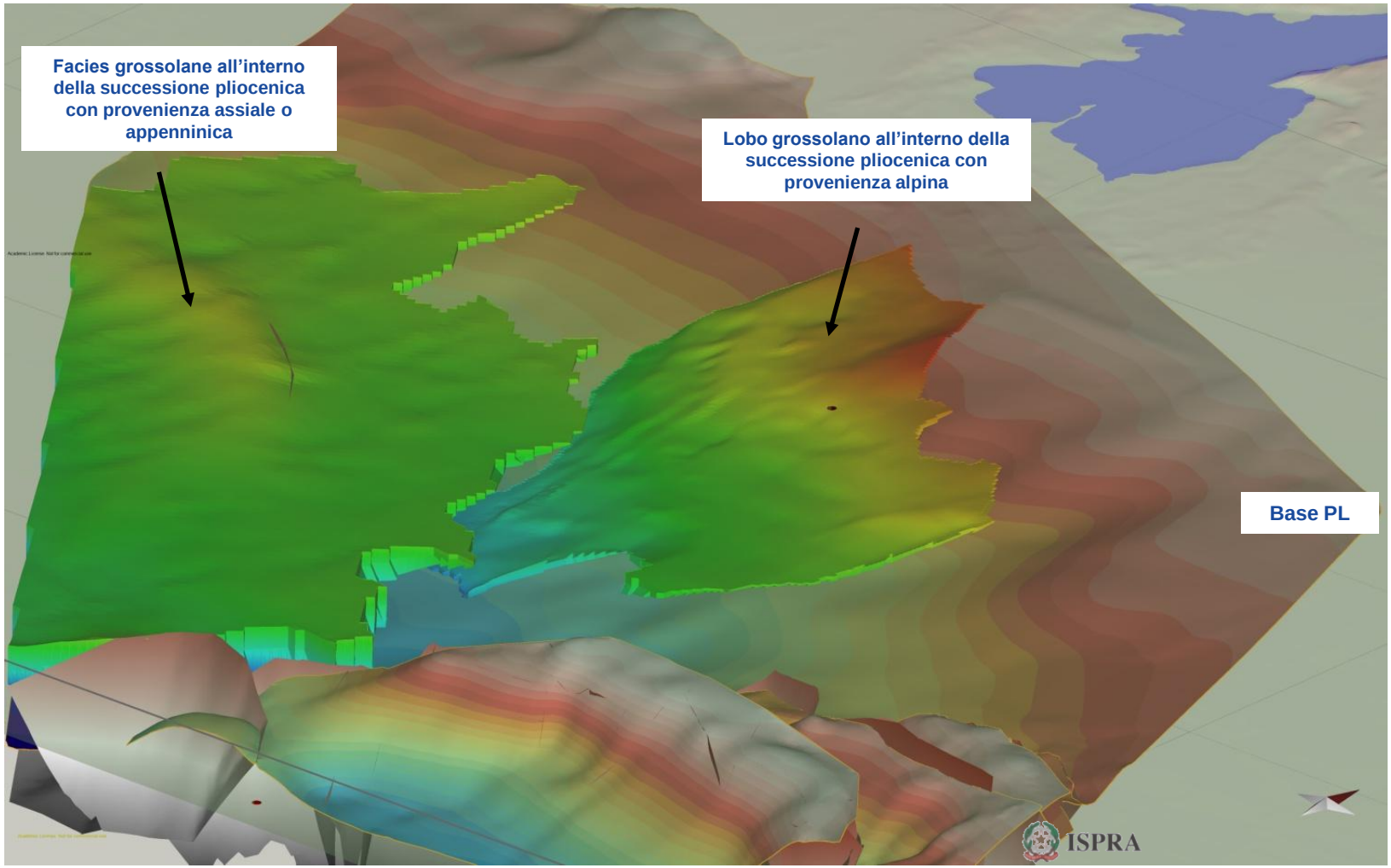


1 – Significativa riduzione della profondità (circa 2000 m) e dell'inclinazione dell'orizzonte

2 – Maggiore dettaglio nella geometria della faglia e della piega

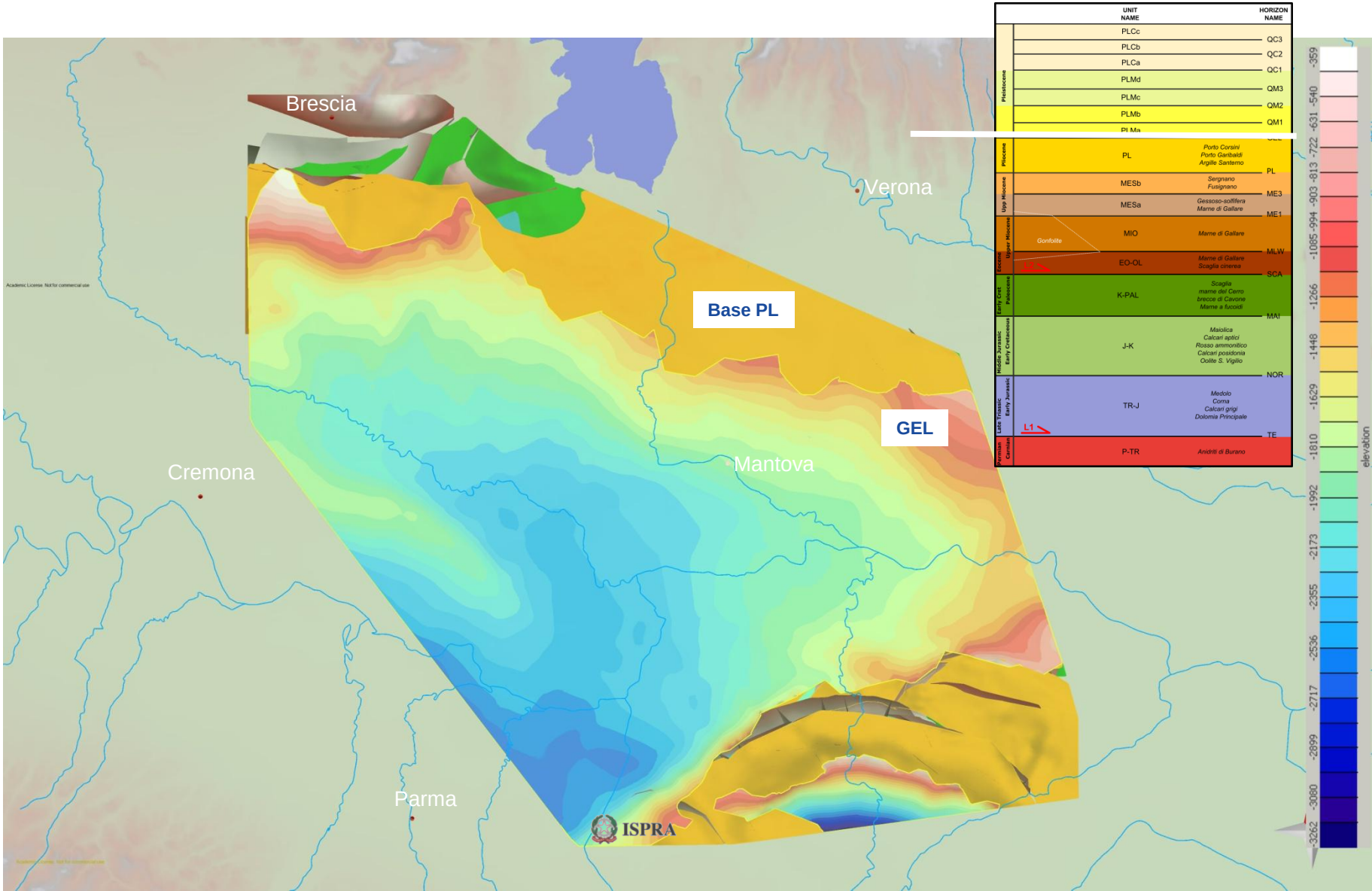
3 – Modificata l'interpretazione della struttura tettonica

Mappatura volumetrica delle facies grossolane per la valutazione dei geopotenziali (geotermia)

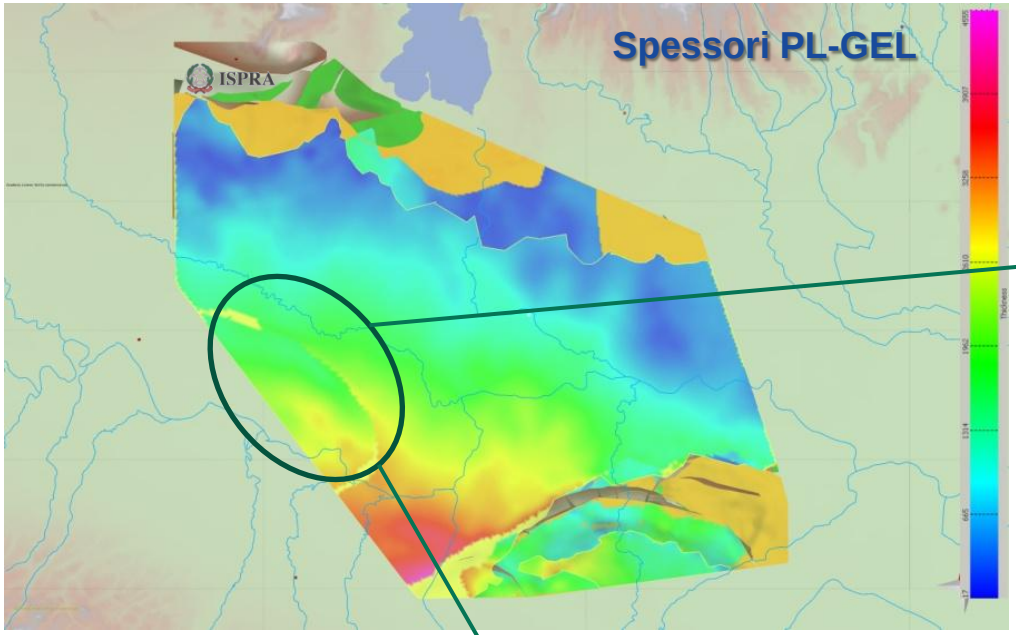


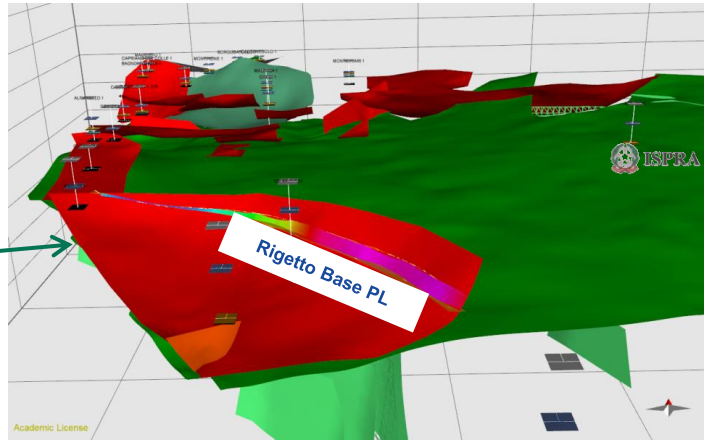
Output verso geotermia

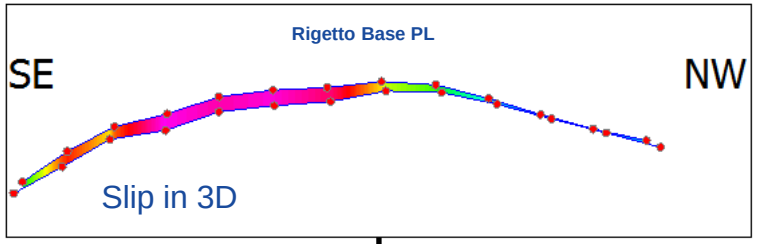
Unconformity gelasiana



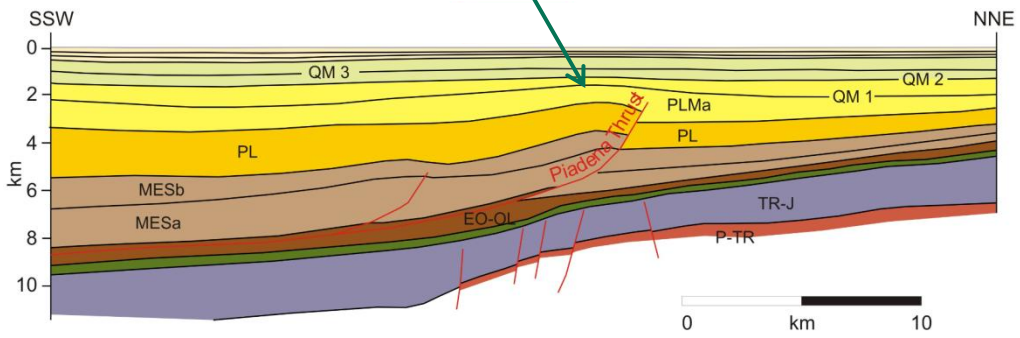
Attivazione dei thrust





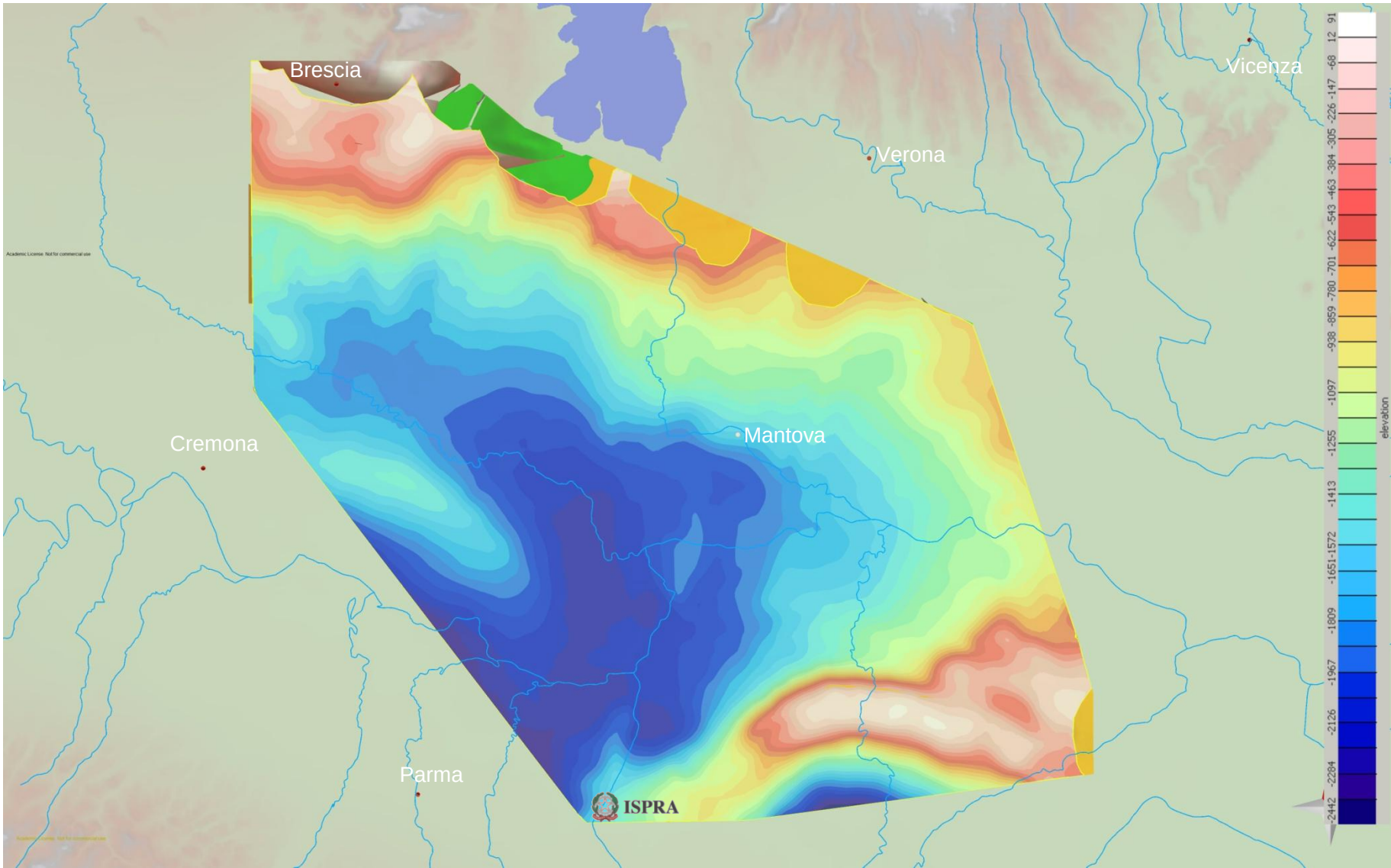


Attivazione della struttura

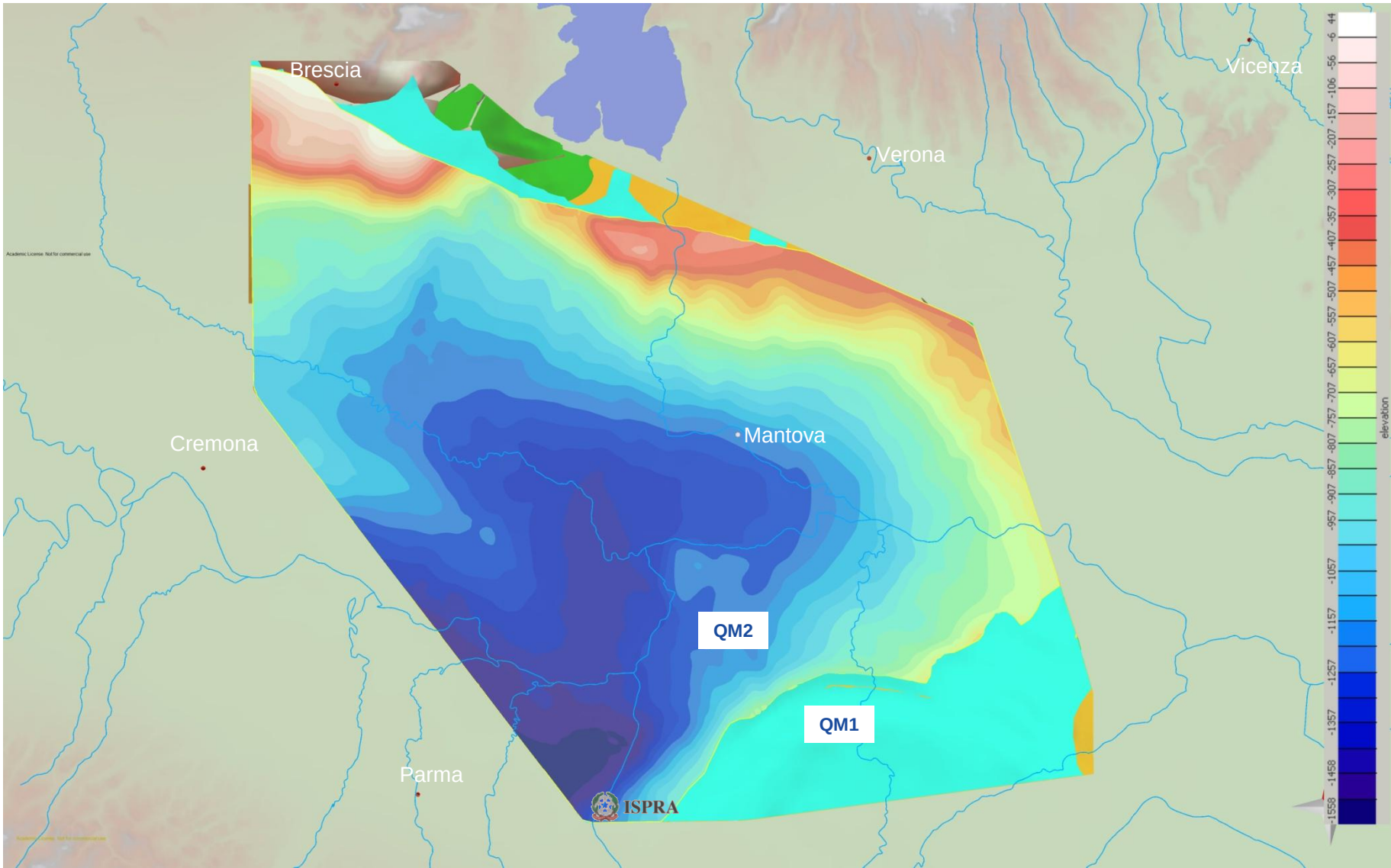


3D slip rates

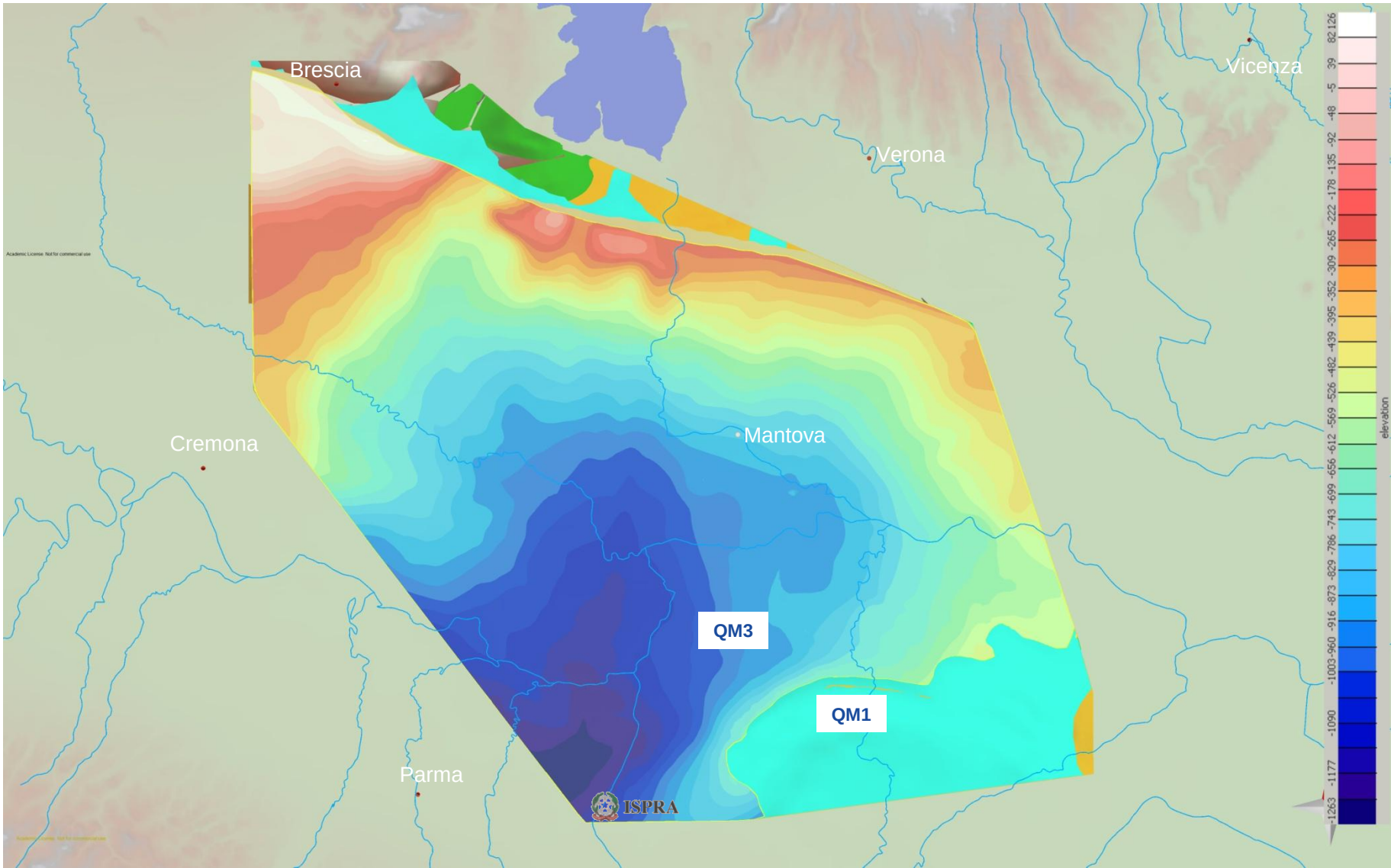
Unconformity QM1 (Calabriano)



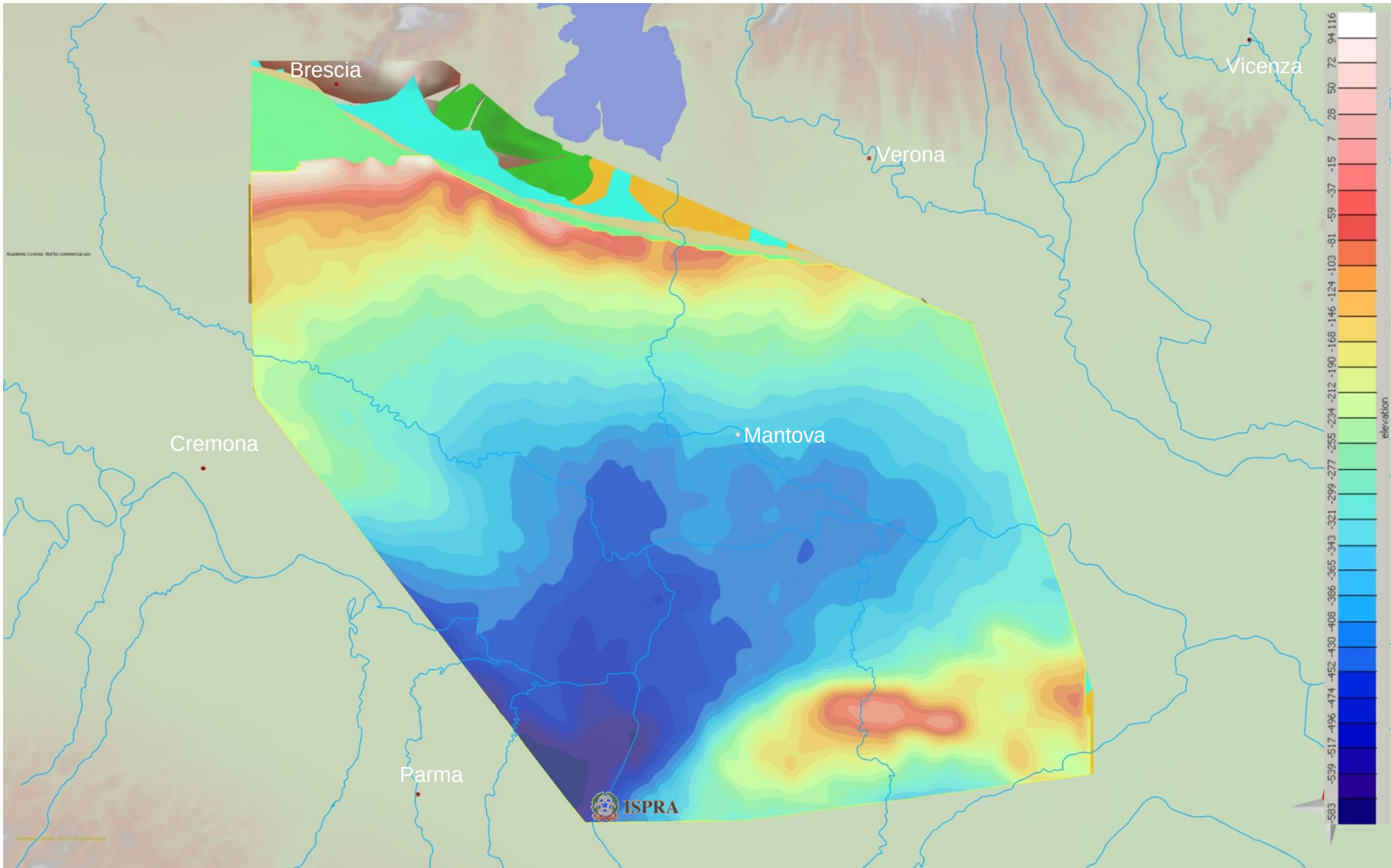
Unconformity QM2 (Calabriano)



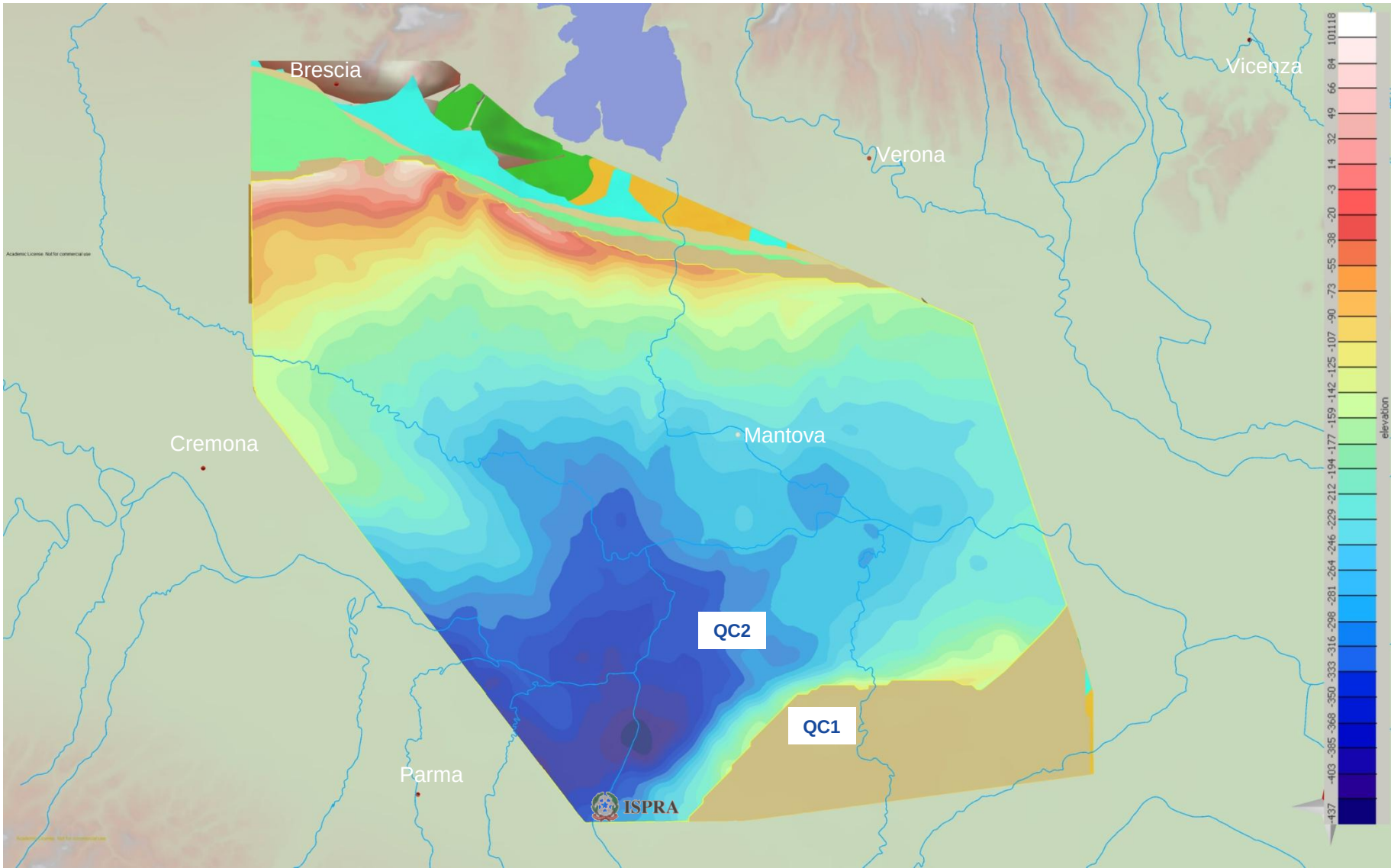
Unconformity QM3 (Calabriano)



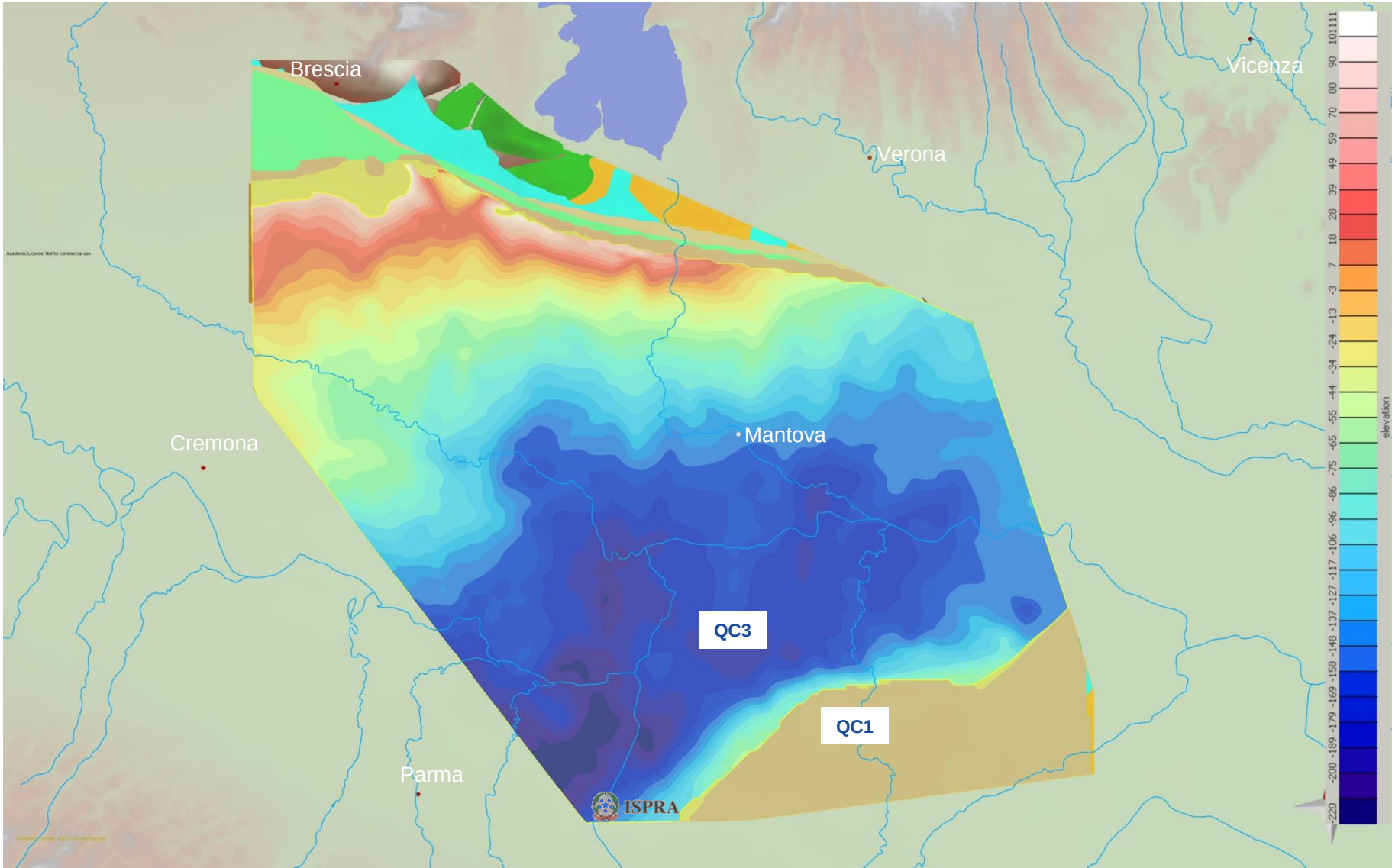
Unconformity QC1 (Pleistocene medio)



Unconformity QC2 (Pleistocene medio)

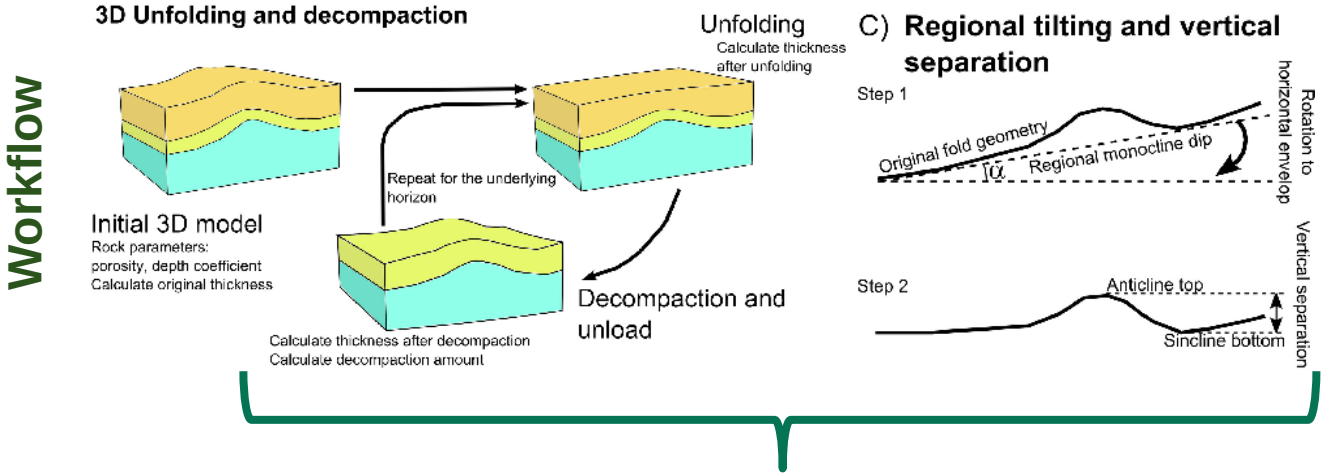


Unconformity QC3 (Pleistocene medio)



Evoluzione del riempimento del bacino durante il Pleistocene

Workflow



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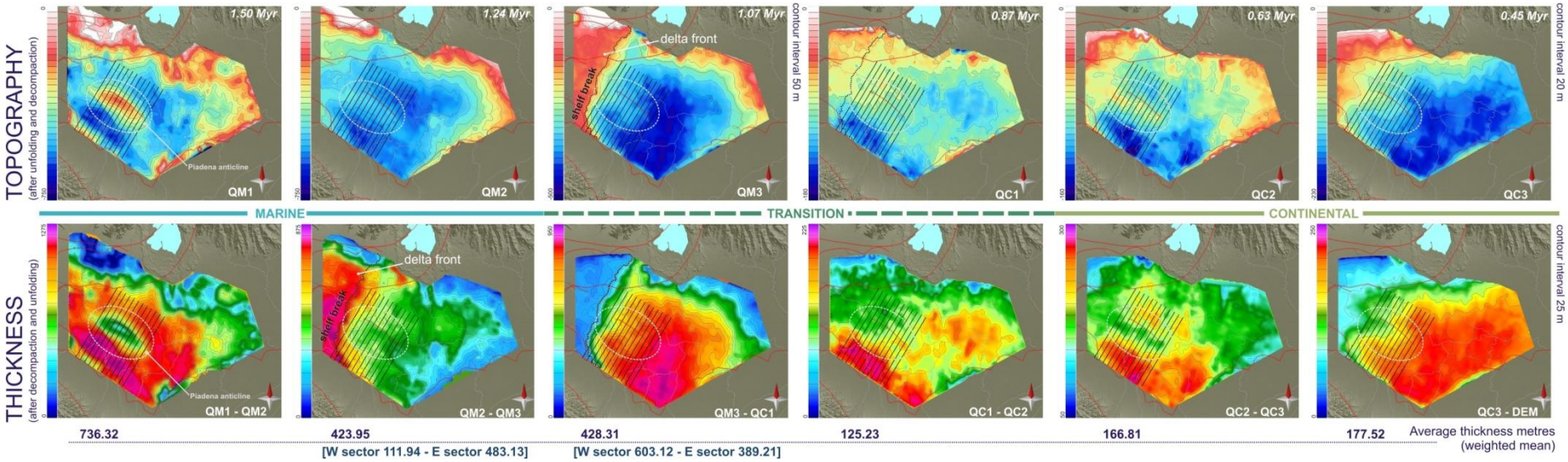
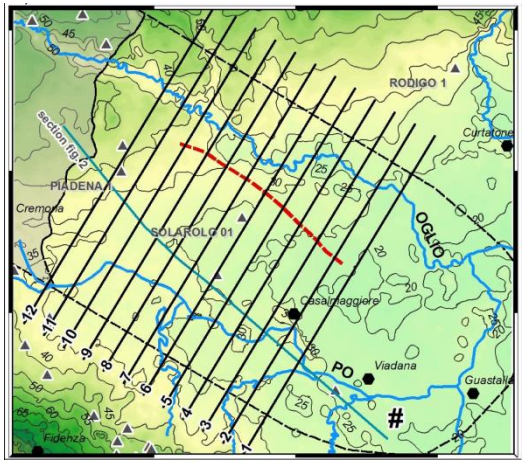
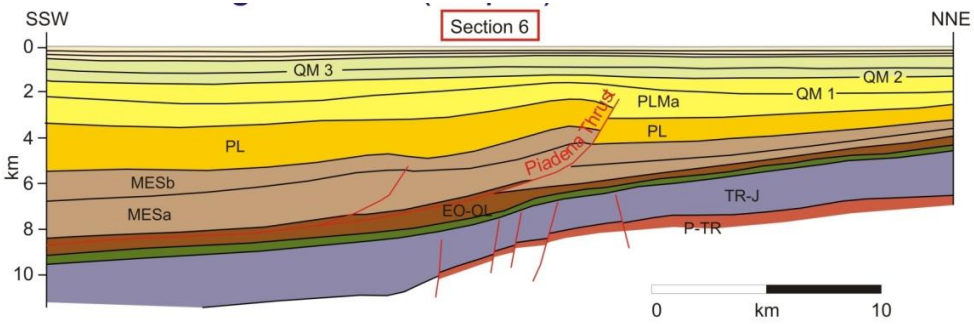


Maesano & D'Ambrogi (under revision) – coupling sedimentation and tectonic control: Pleistocene evolution of the Central Po Basin – It. Jour. Geosc.

Interazione tra tettonica e sedimentazione





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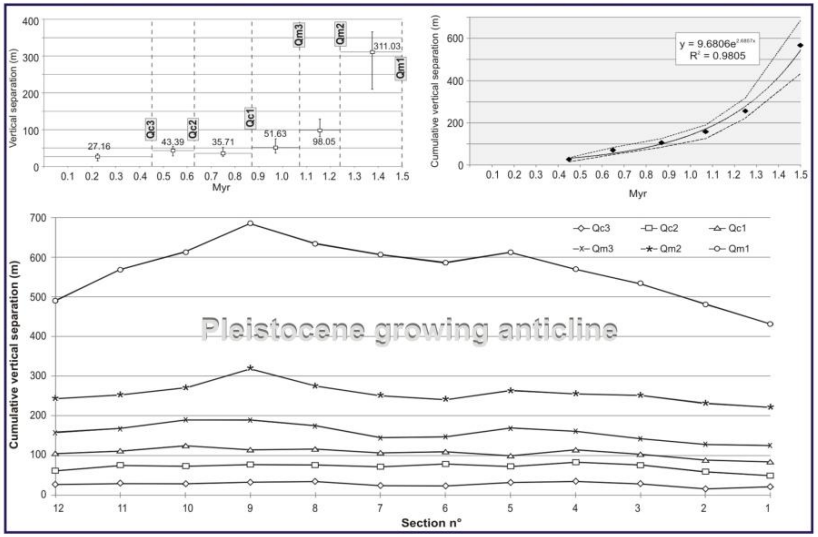
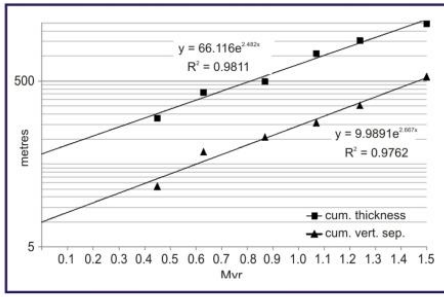
RESIDUAL VERTICAL SEPARATION



SEDIMENTATION vs UPLIFT RATE



	sedim rate (mm/yr)	uplift rate (mm/yr)
Qc3-DEM	0.40 ± 0.05	0.06 ± 0.05
Qc2-Qc3	1.04 ± 0.17	0.24 ± 0.12
Qc1-Qc2	0.54 ±0.11	0.15 ± 0.09
Qm3-Qc1	2.91 ± 0.25 #	0.26 ± 0.11
Qm2-Qm3	2.71 ± 0.28 #	0.58 ± 0.15
Qm1-Qm2	3.59 ± 0.21	1.20 ± 0.12

The sedimentation rates are calculated for the Piadena area

Maesano & D'Ambrogi (under revision) – coupling sedimentation and tectonic control: Pleistocene evolution of the Central Po Basin – It. Jour. Geosc.

Dal modello geologico 3D agli output tematici

Modello 3D GeoMol

Sismotettonica

Assi anticlinali → orizzonte deformato più giovane
Faglie → orizzonte fagliato più giovane
Faglie → parametri geometrici e cinematici (profondità, azimuth/dip)

Geotermia

Unità geologiche alla profondità X
Geologia alle isoterme
Profondità degli orizzonti target

Dal modello geologico 3D agli output tematici

Modello 3D GeoMol

Sismotettonica

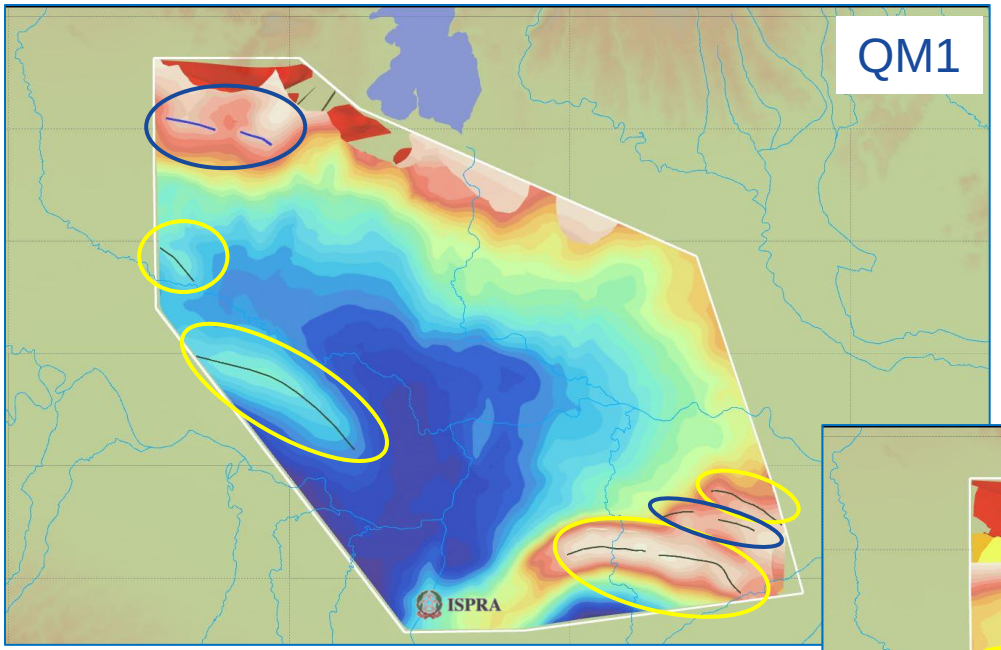
Assi anticlinali → orizzonte deformato più giovane
Faglie → orizzonte fagliato più giovane
Faglie → parametri geometrici e cinematici (profondità, azimuth/dip)

Faglie attive
Sorgenti sismogenetiche

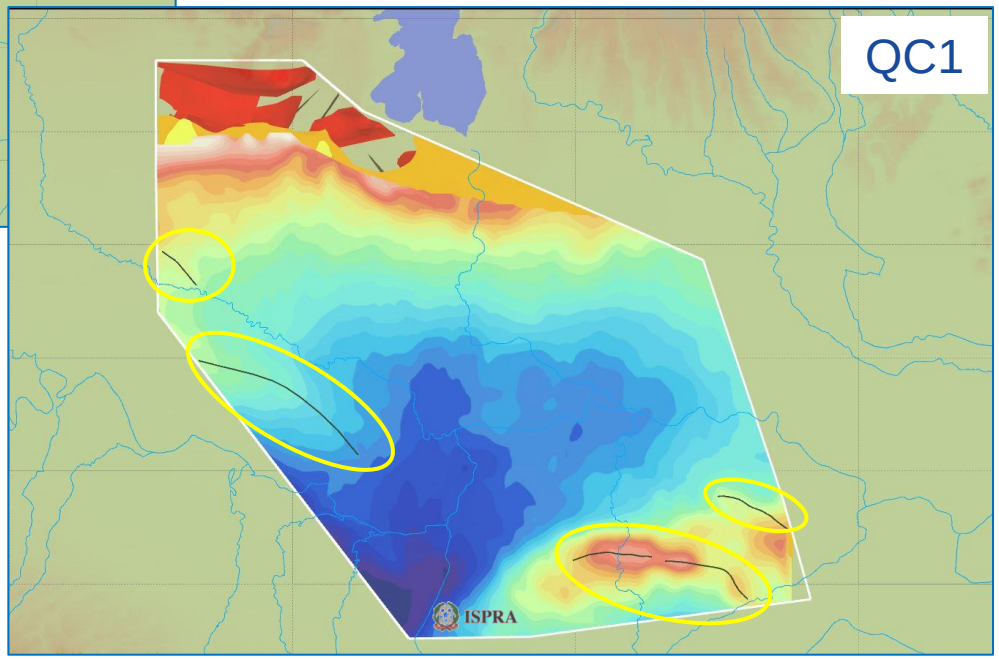
Geotermia

Unità geologiche alla profondità X
Geologia alle isoterme
Profondità degli orizzonti target

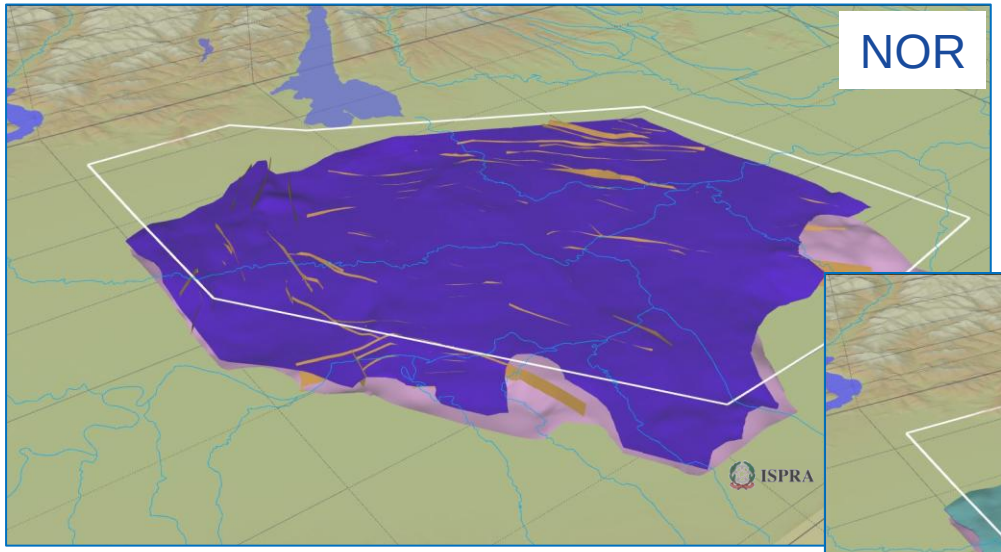
Geo-potenziali

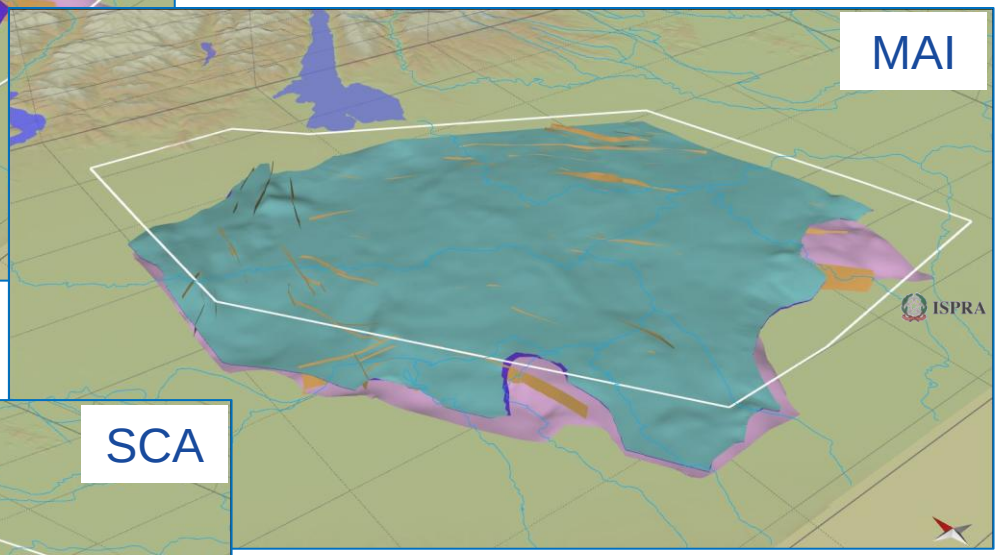


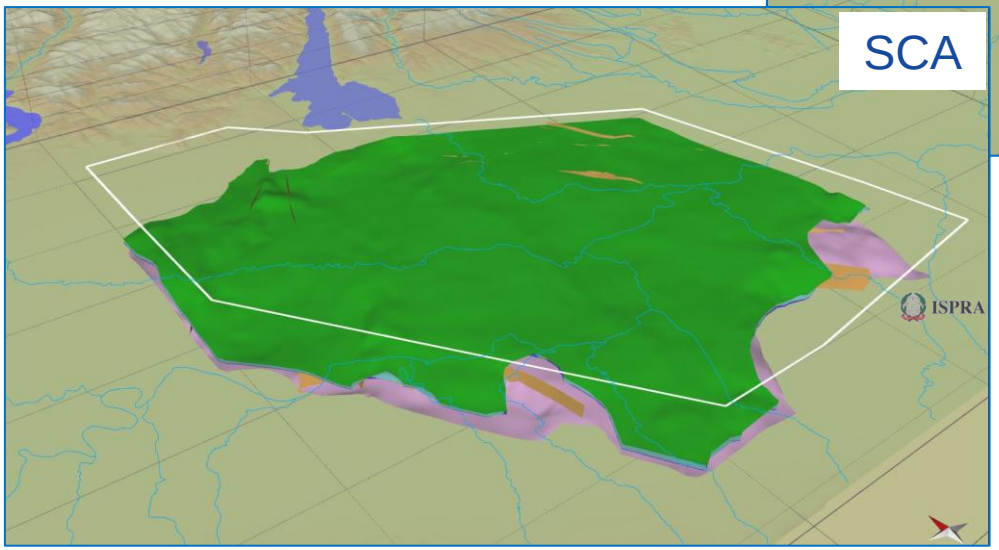
ANTICLINALI
Età orizzonte deformato più giovane

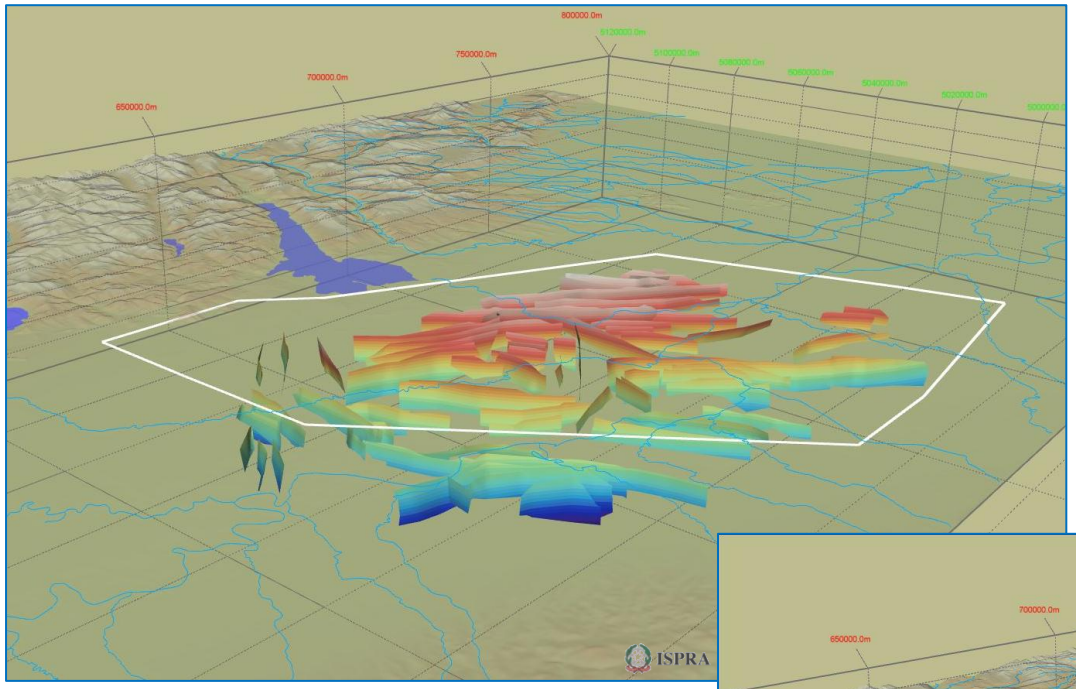


FAGLIE
Età orizzonte fagliato più giovane

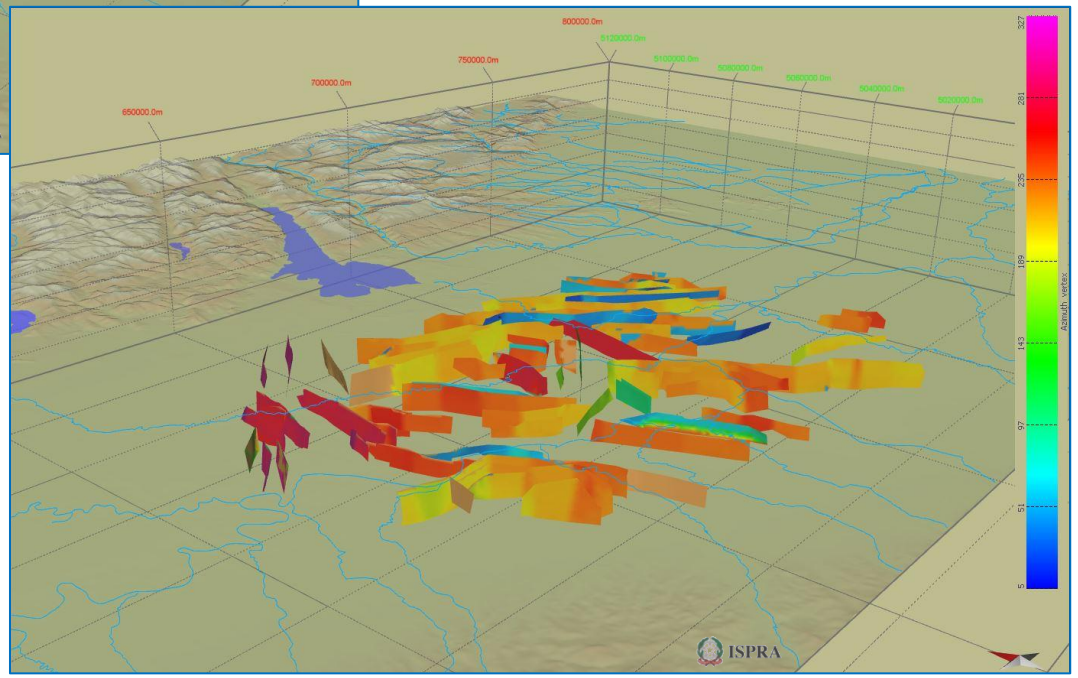




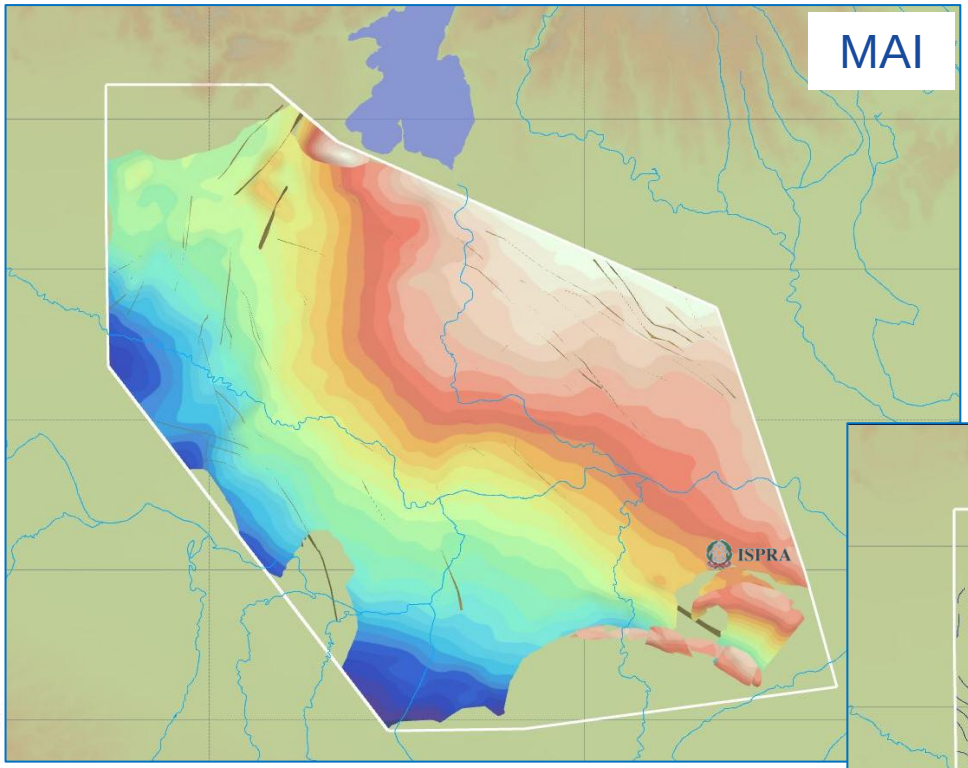


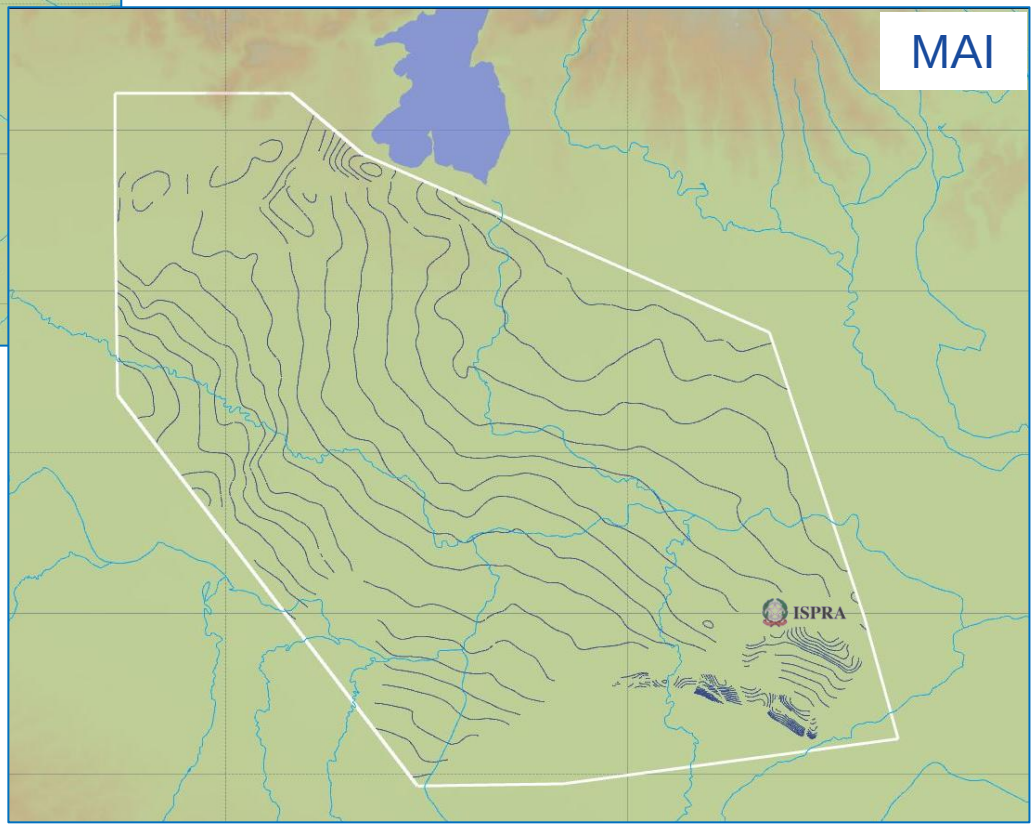


FAGLIE
Parametri



ISOBATE
Orizzonte target





ISOPACHE

Orizzonte target/evoluzione strutture