Vp-Vs measurements of shallow formations in Chémery (FR): comparison between laboratory and field data and integration within a 3D geological model

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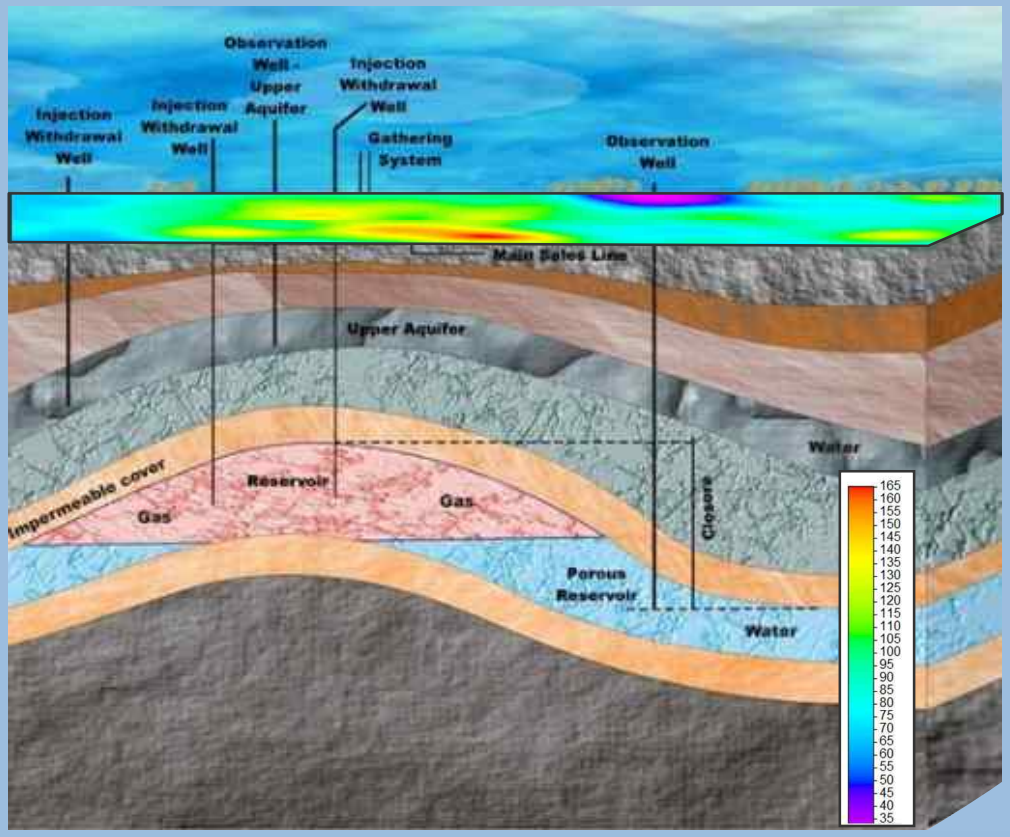
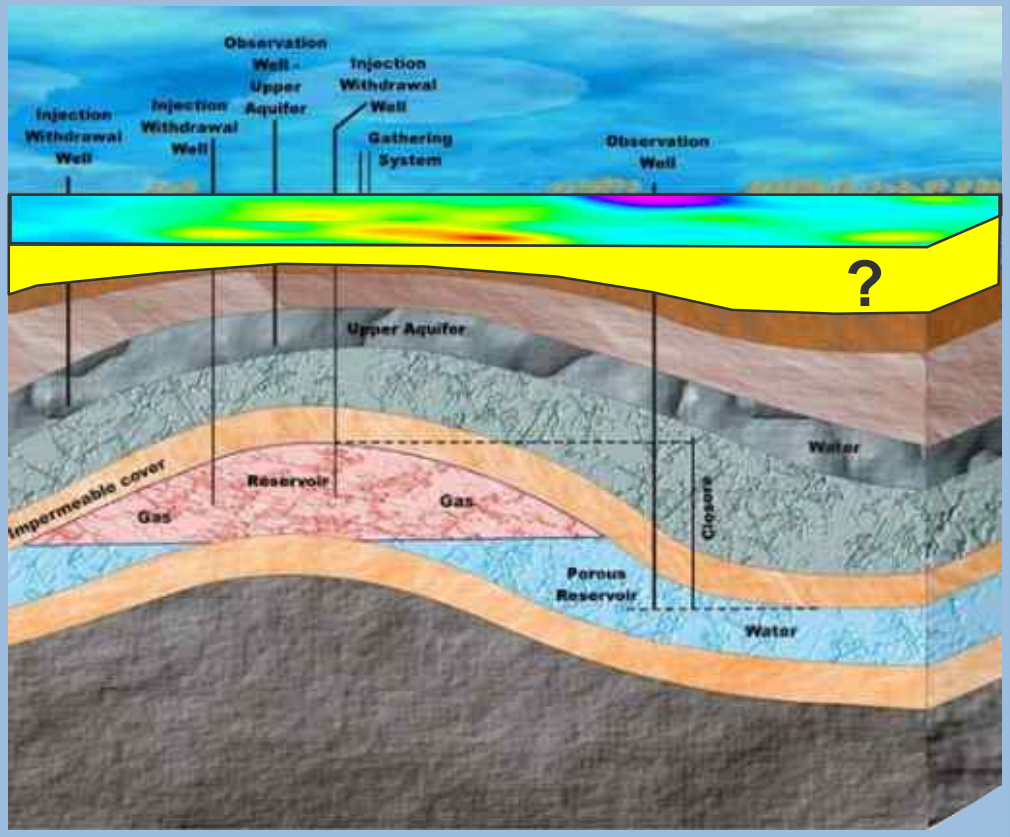
Underground Gas Storage analysis



Example of PSD-IZ grid draped over a schematic representation of an underground storage facility

- Low frequency seismic:
  - Hydrocarbon detection (Saenger et al 2009)
- Method used to define a gas cushion areal extension in an underground gas storage facility (Artman et al 2011)

Aim of the project



> To understand the influence of the near surface wavefield, characterize the first 100 meters of the subsurface in terms of:

- Geology
- Velocity field

> Produce a realistic model suitable for further geophysical and geostatistical analysis

Method

- Creation of a three-dimensional geological framework
- Implementation with field and laboratory data
  - Velocity logs
  - Vp and Vs measurements on dry and saturated samples

Study area

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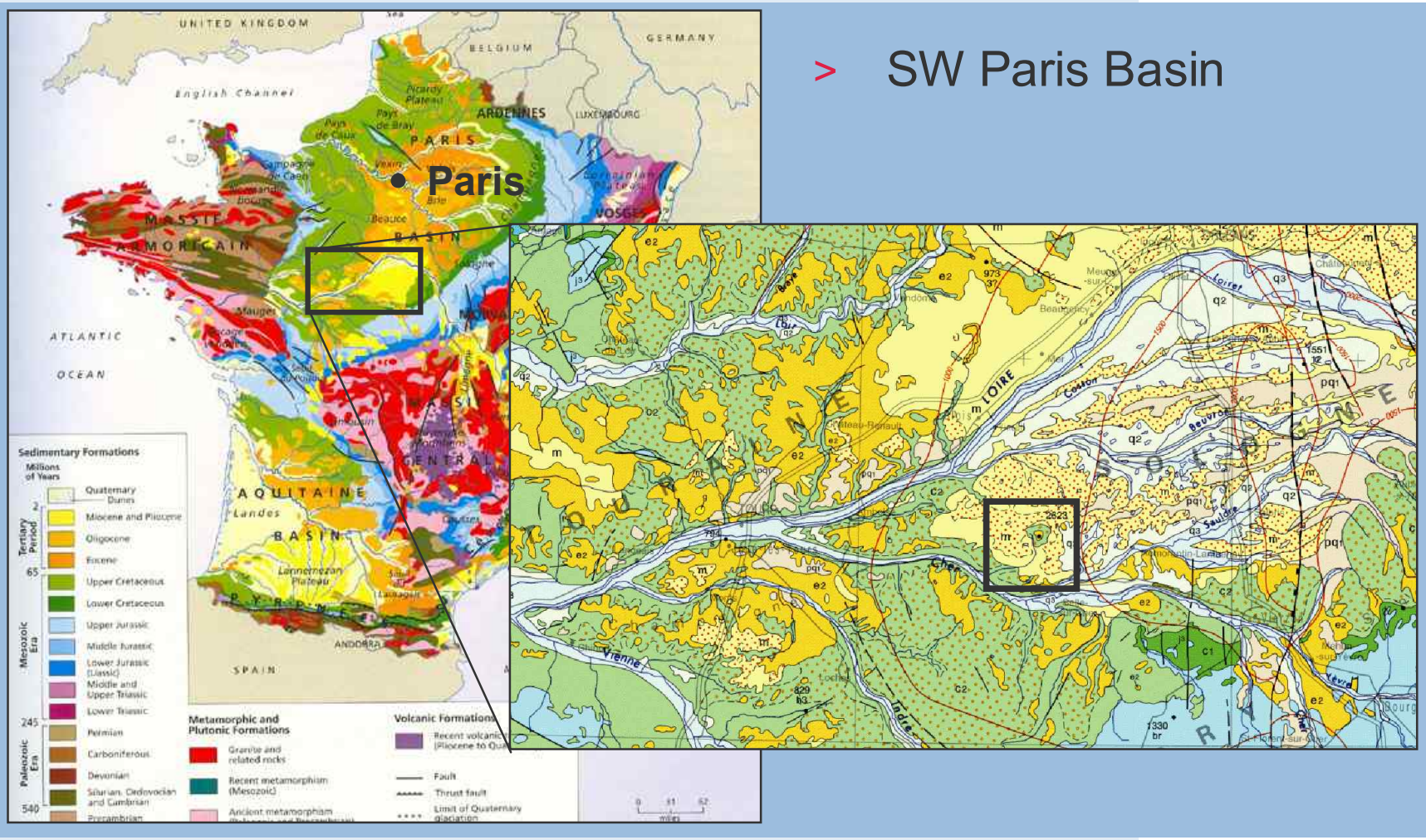
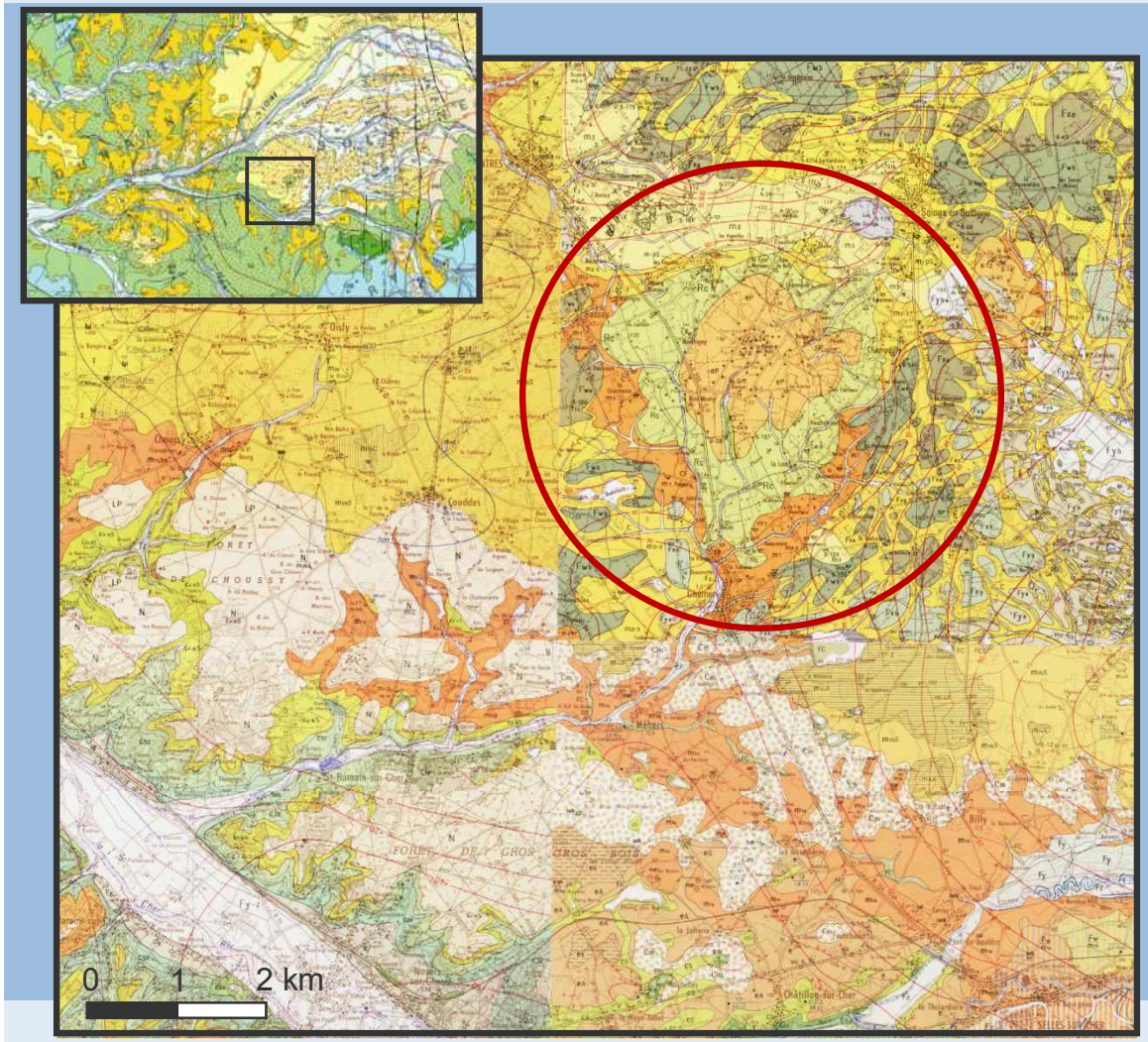
> SW Paris Basin

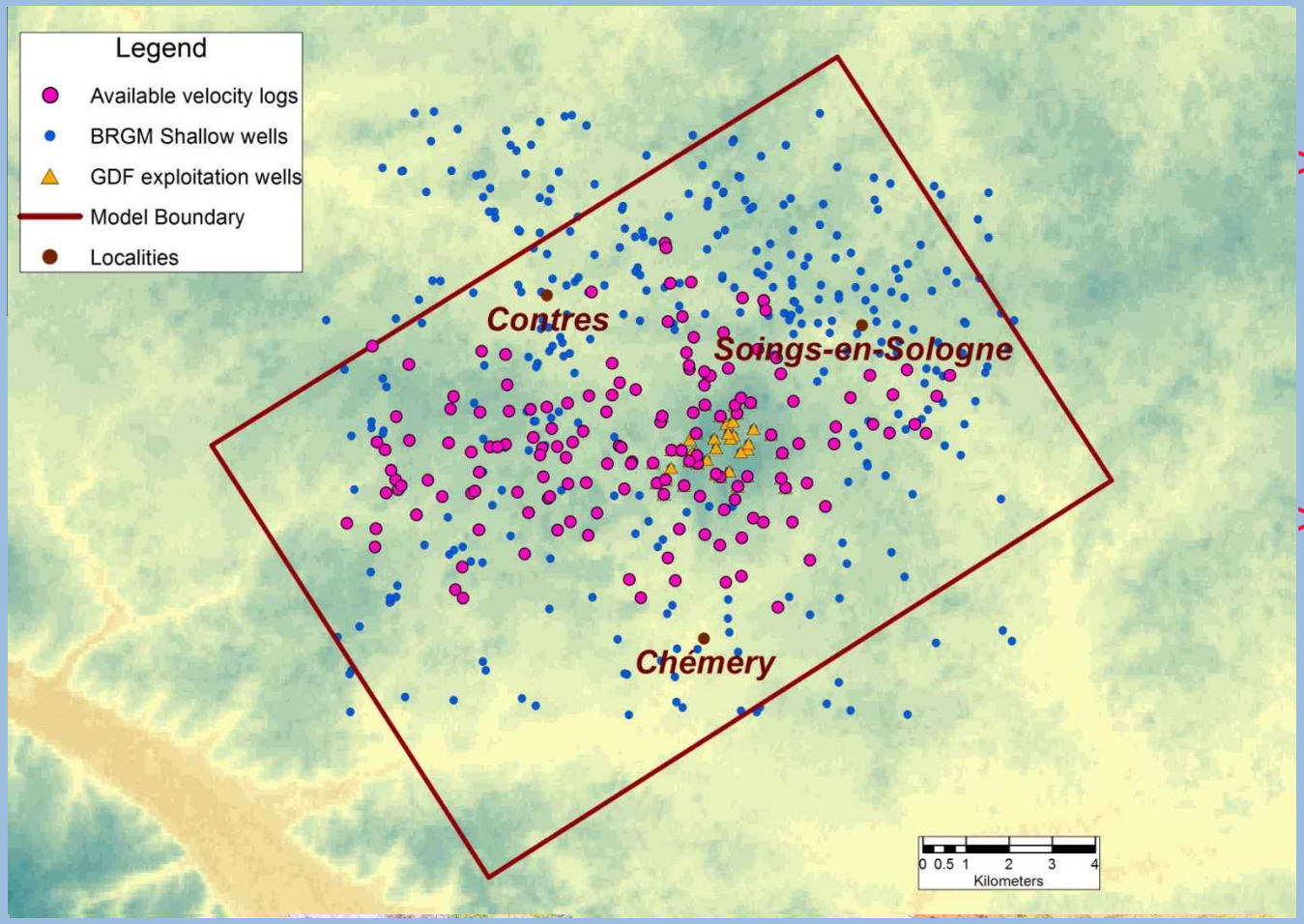


Shallow surface stratigraphy



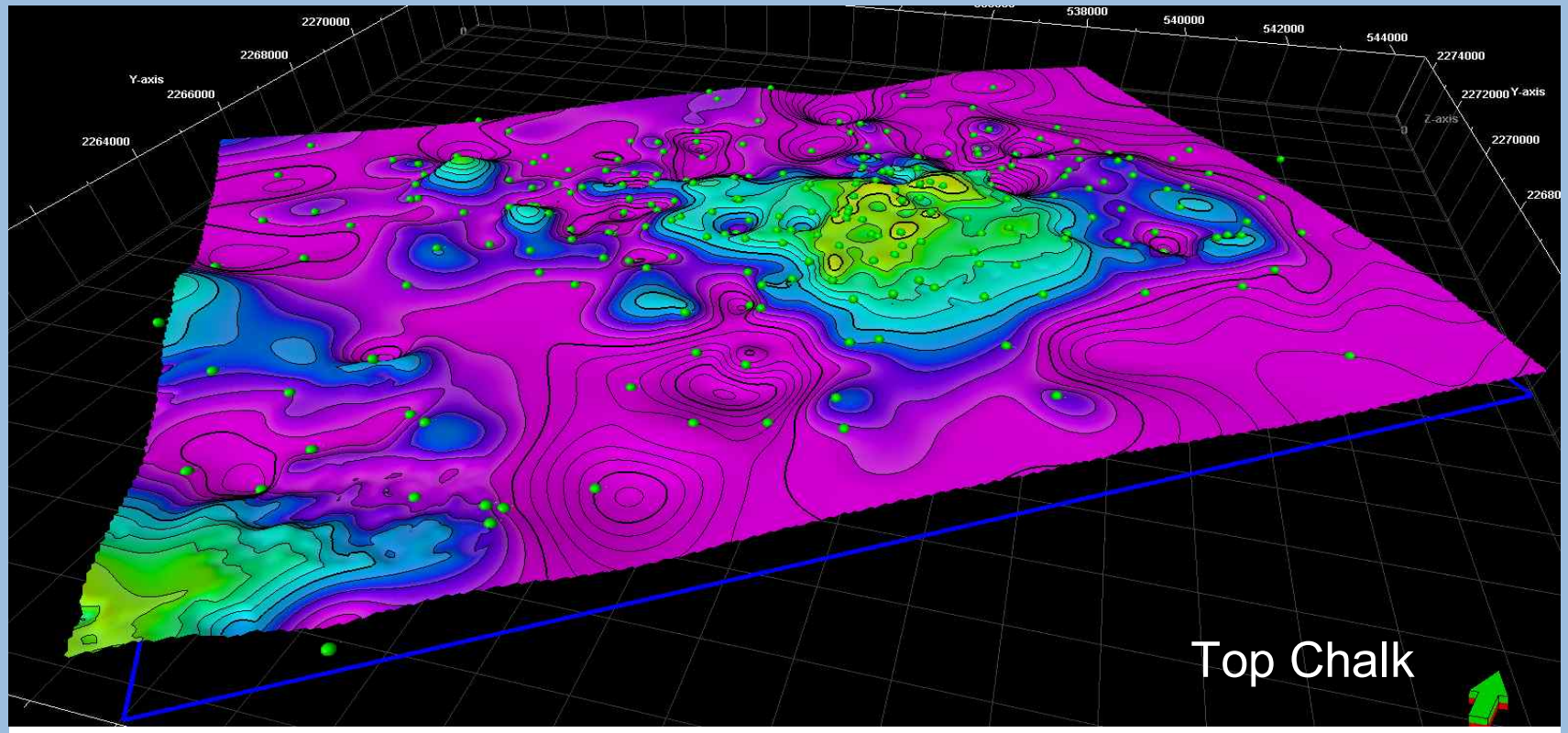
Age		Sedimentary Structures	Formations	
			Recent alluvial	
Pliocene			Sables et Argiles de Sologne	SAS
Miocene	Langhian		Faluns de Touraine	FALUNS
	Burdigalian		Sables et Marnes de l'Orléanais et du Blésois	SMOB
Oligocene	Rupelian-Aquitanian		Calcaire de Beauce	BEAUCE
Paleocene-Eocene			Formations Détritiques Continentales	FDC
			Argiles à Silex	FRS
Upper Cretaceous	Senonian		Craie blanche à Silex: Romorantin / Villedieu / Blois	CHALK
	Turonian		Tuffeau Jaune de Touraine	TJT
			Tuffeau de Bourré	TB
			Craie à Inocerames	CI
	Cenomanian		Marnes à Huîtres	

Model extent



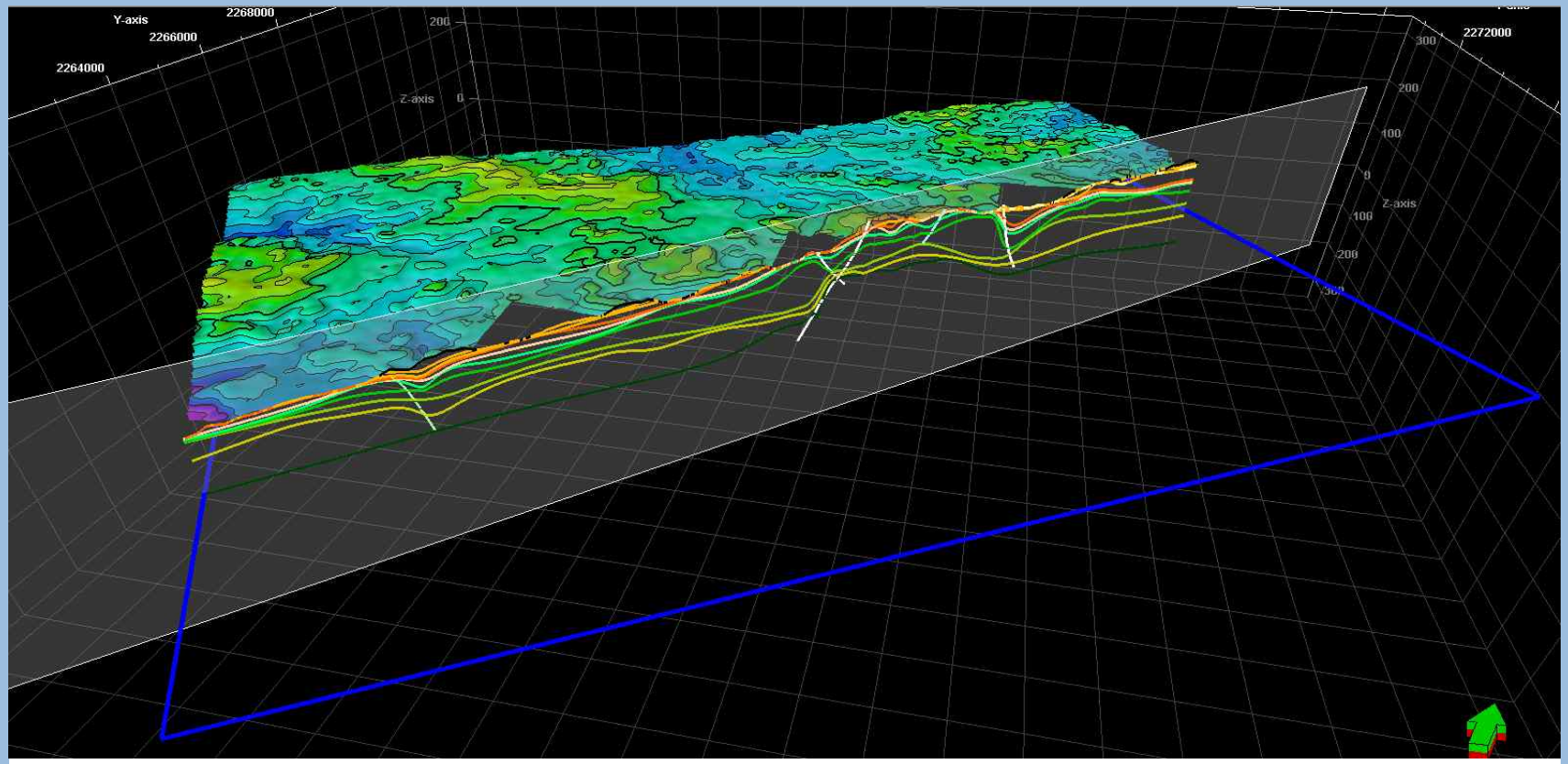
- 187 km²
  - Passive seismic survey
  - 400 Well data
- Vertical extension: 100-300 m

Toward the geometrical container: surfaces & faults



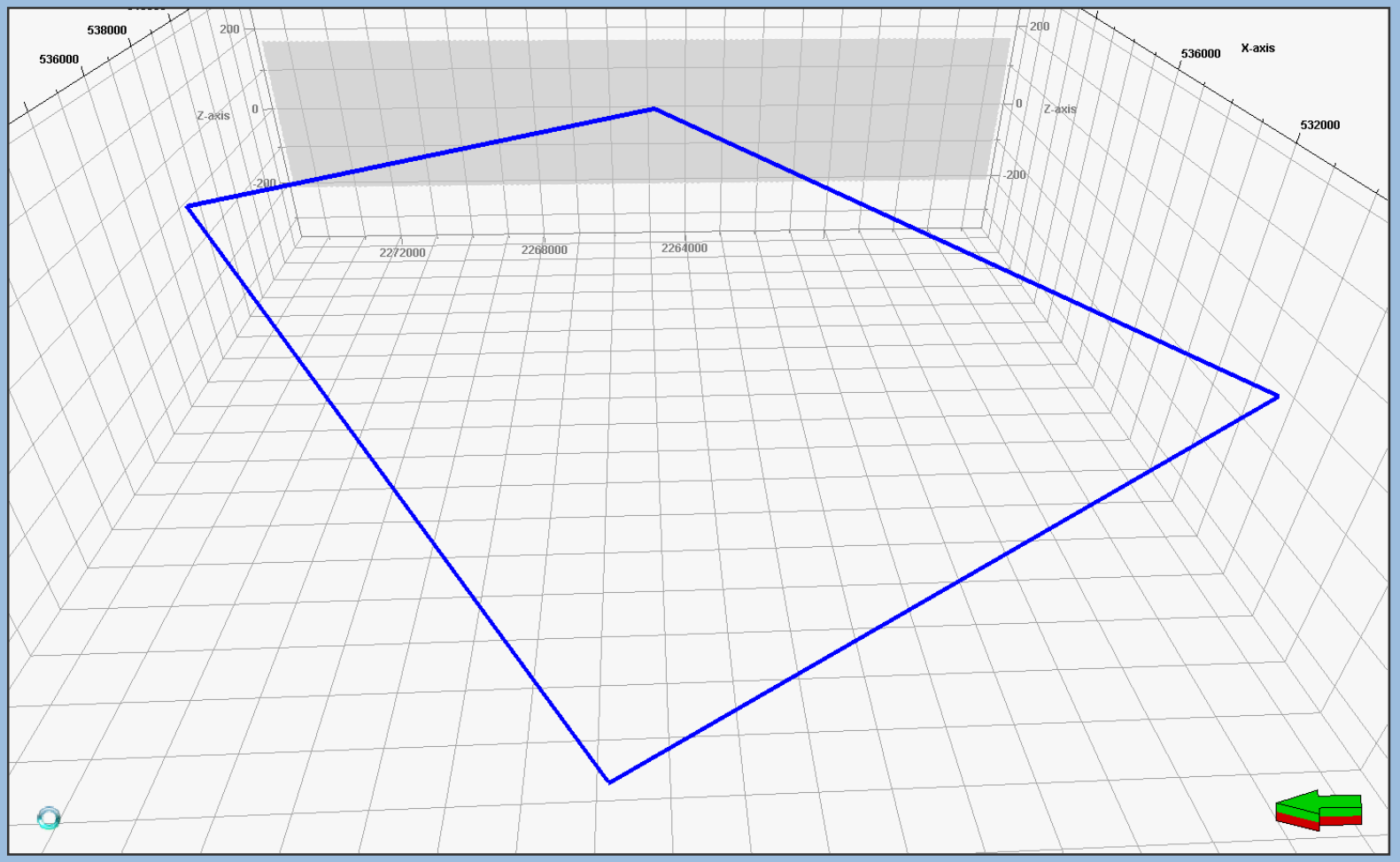
- Surfaces created based on a convergent interpolation algorithm
- Algorithm guided with additional control points to avoid surfaces cross-cutting relationships

Toward the geometrical container: surfaces & faults



- Not classical interpretation workflow
- Fault traced basing on the maximum curvature of the surfaces

Model overview



Velocity modeling results

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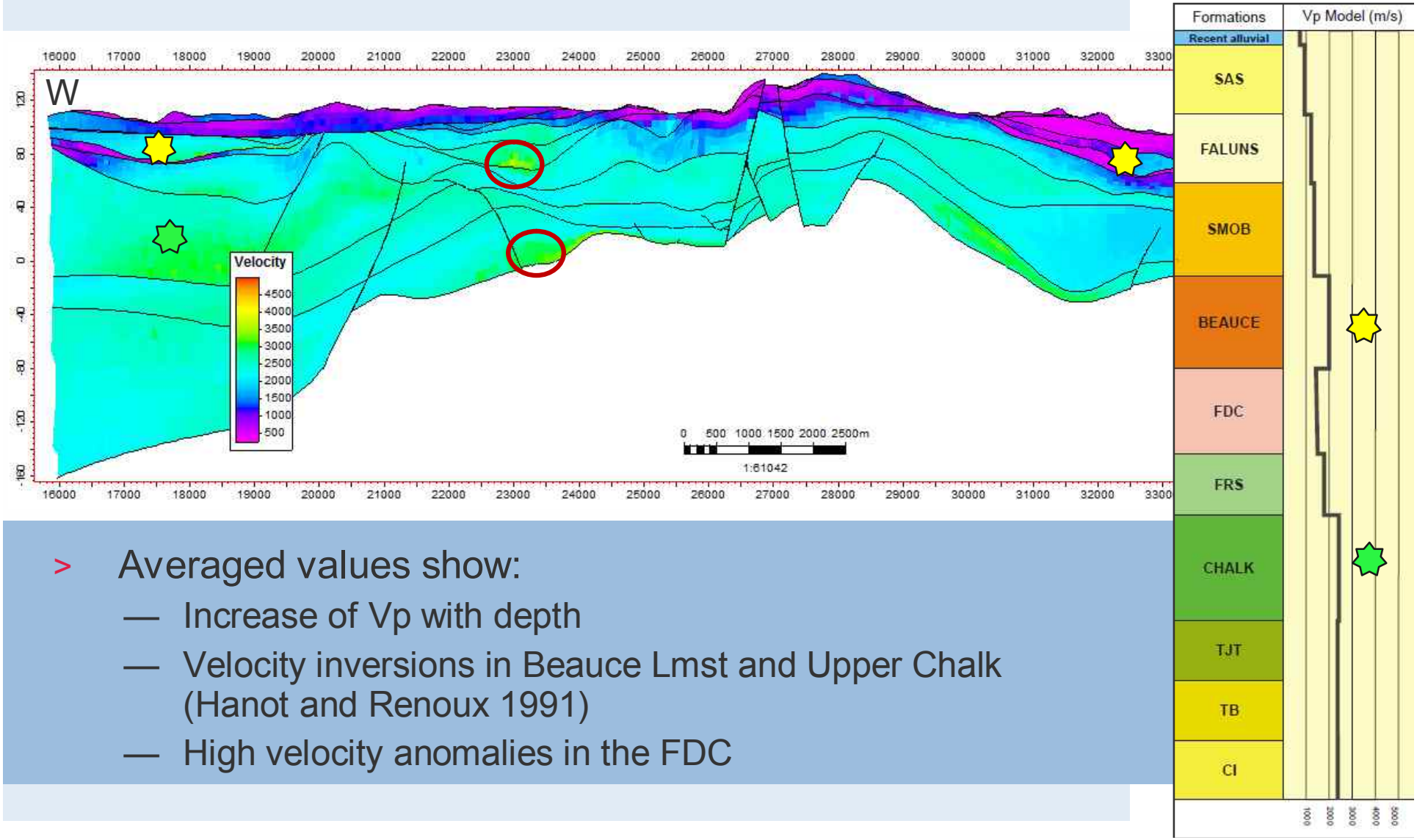
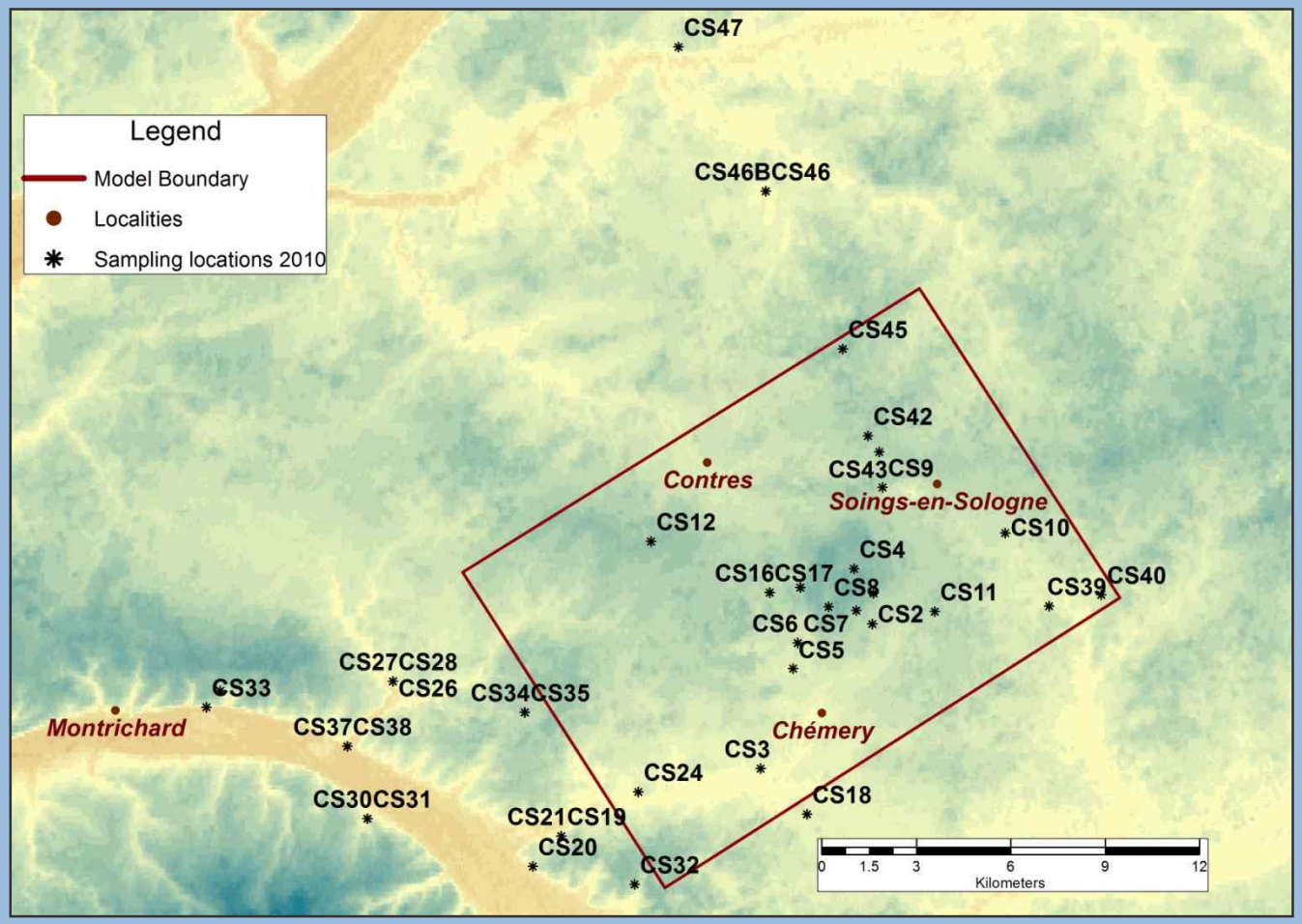


- Averaged values show:
  - Increase of Vp with depth
  - Velocity inversions in Beauce Lmst and Upper Chalk (Hanot and Renoux 1991)
  - High velocity anomalies in the FDC

Sampling



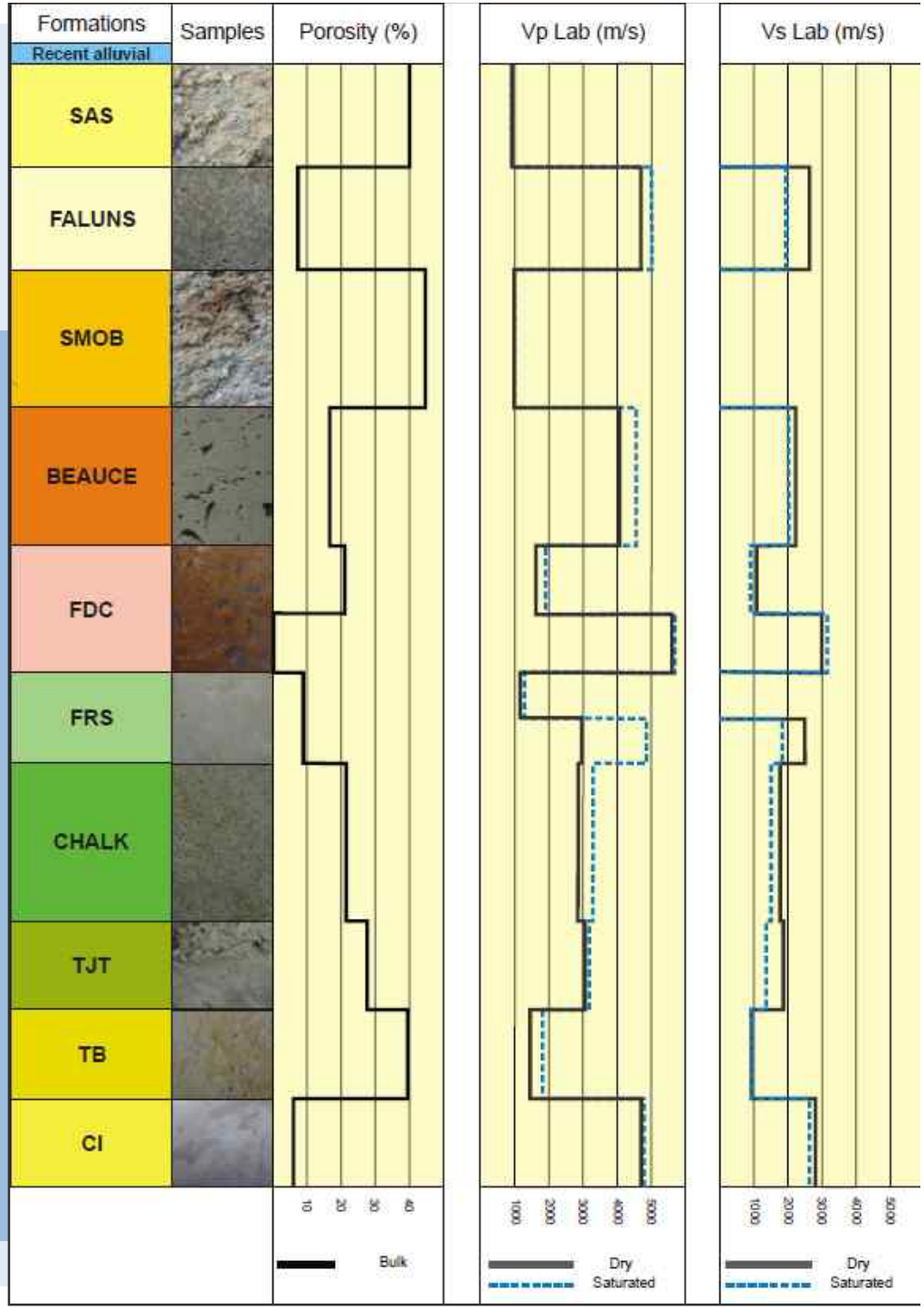
- About 50 samples
- Mostly calcarenites
- Few samples from the shallowest formations

Laboratory measurements

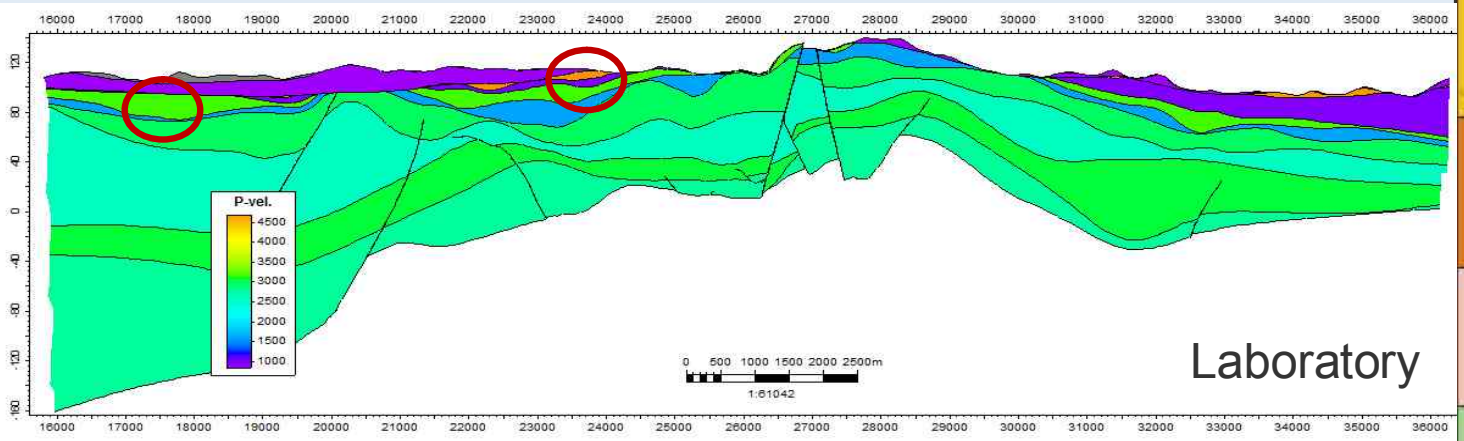
- Pulse transmission method (Birch, 1960) for compression (Vp) and shear (Vs) waves in dry and ~fully water saturated conditions
- Frequency: 0.1 MHz
- Porosity measurements with helium pycnometer

Lab results

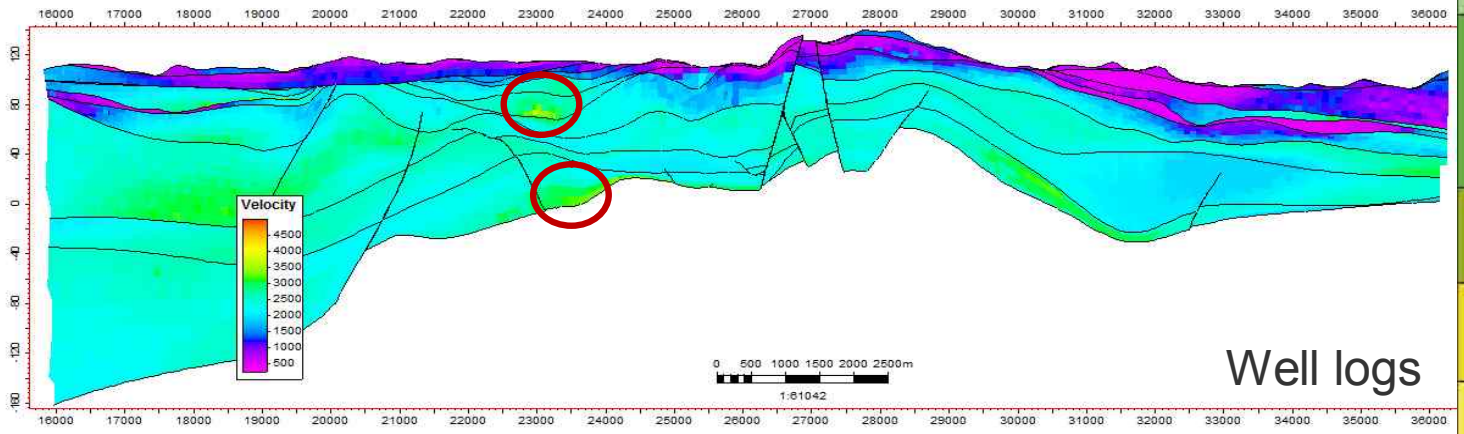
- Measurements show:
  - In fully saturated conditions, Vp values increase on average by 10% while the Vs values decrease on average by 15%.
  - Similar trends observed in the literature (Cadoret et al., 1992).
  - Alteration of outcrop samples
  - Different facies



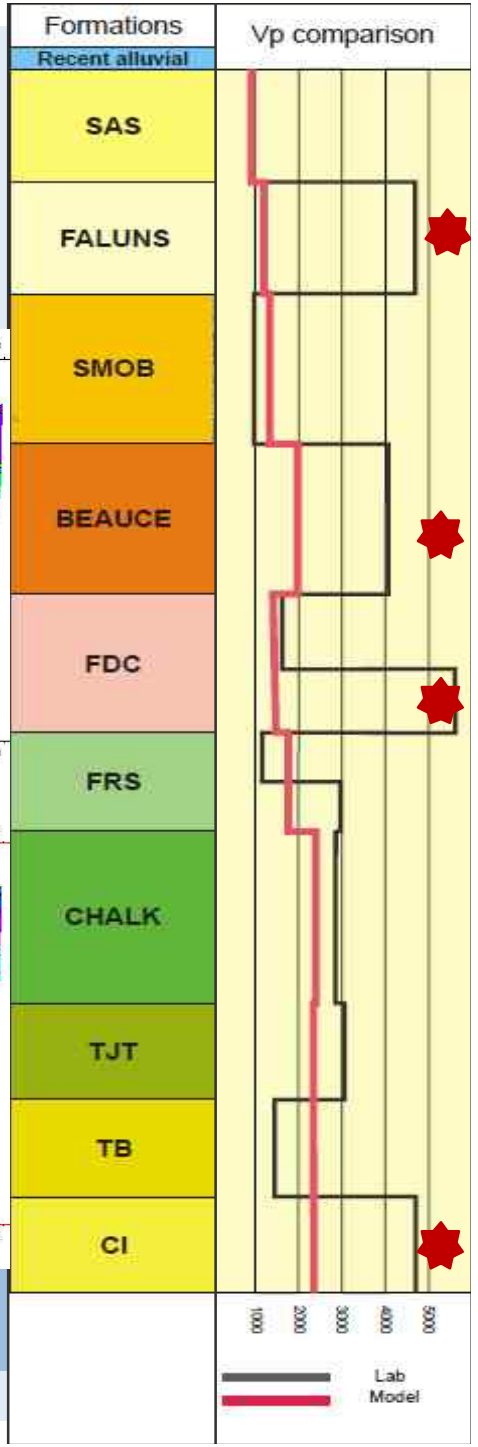
Comparison lab – well logs



Laboratory



Well logs



Strong inversions in the lab model due to differences in the formations diagenesis

Dry vs Saturated models

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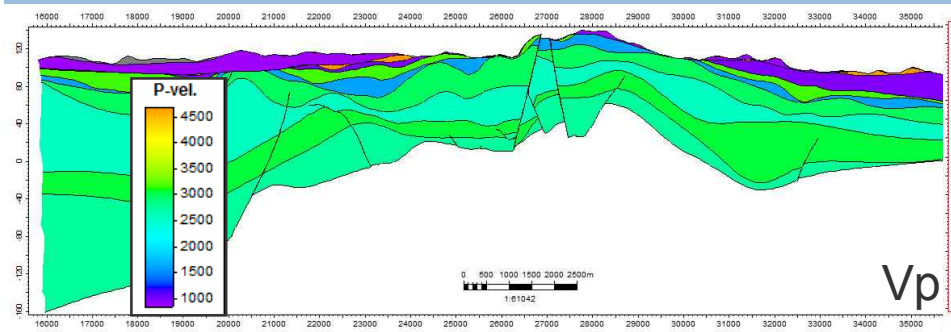
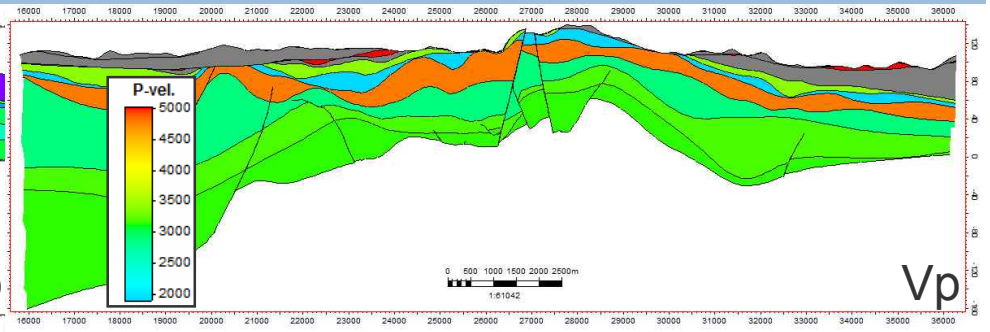
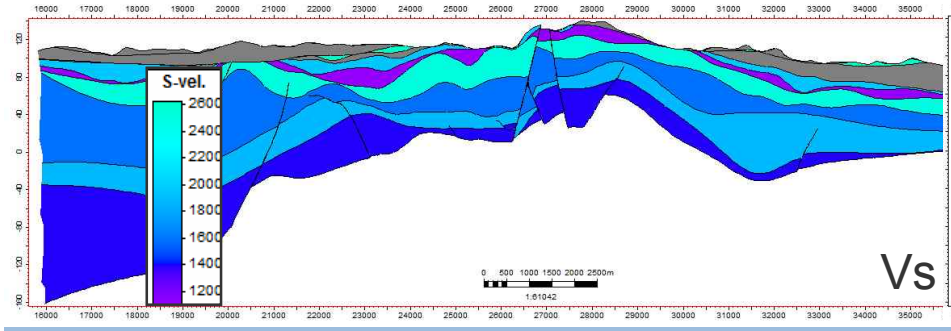
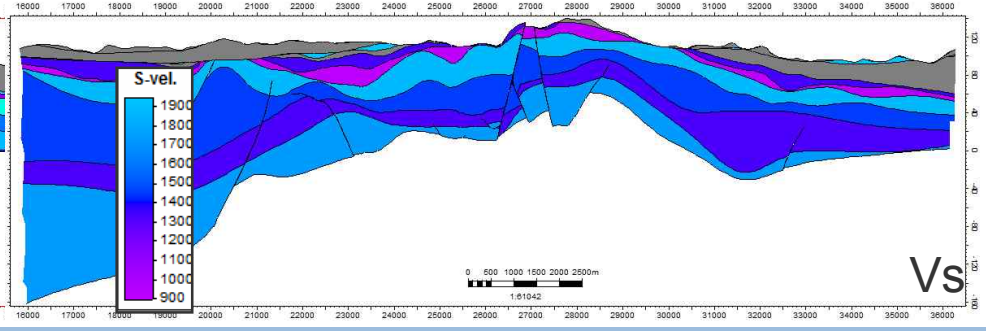
Dry

Saturated





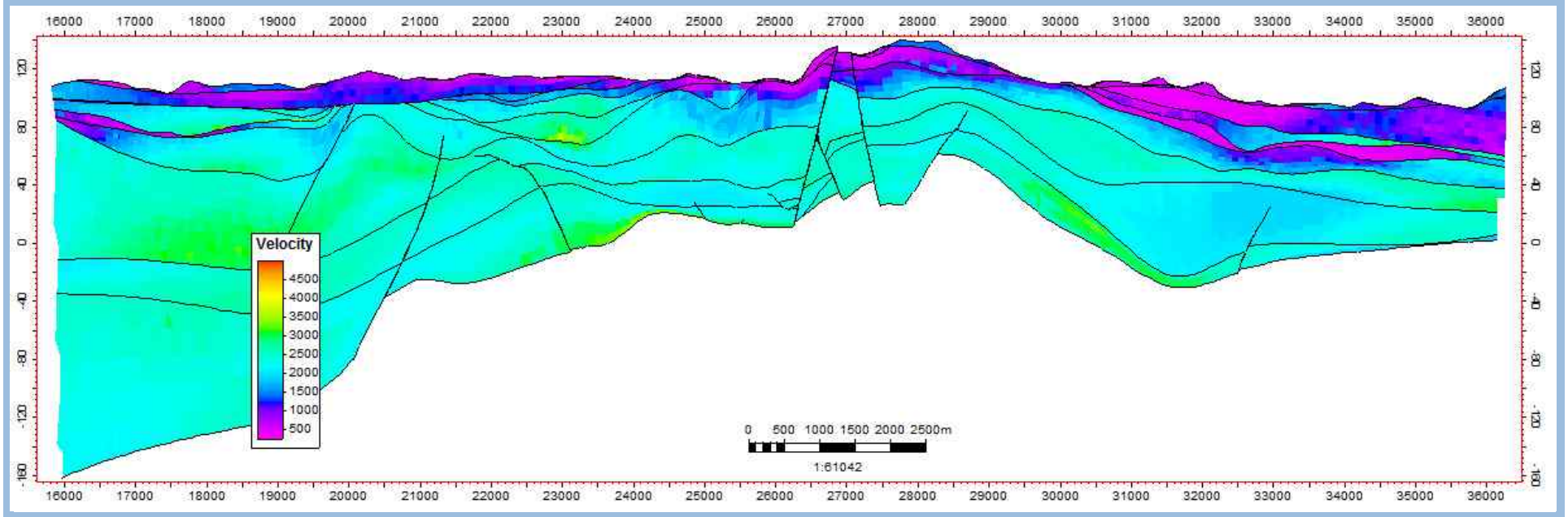




Conclusions

- Generation of a 3D geological and velocity model
- Comparison with laboratory data:
  - Certain correlation between lab and field data
  - Limitations: not all the lithologies are measurable in the lab
  - Well measurements: fracturation
- Find another way to constrain velocity from the lab into the model
  - Upscaling to correct frequency

Outlook-
Facies modeling to constrain velocity



> Use facies distribution as a tool for a better understanding and estimation of the velocity field

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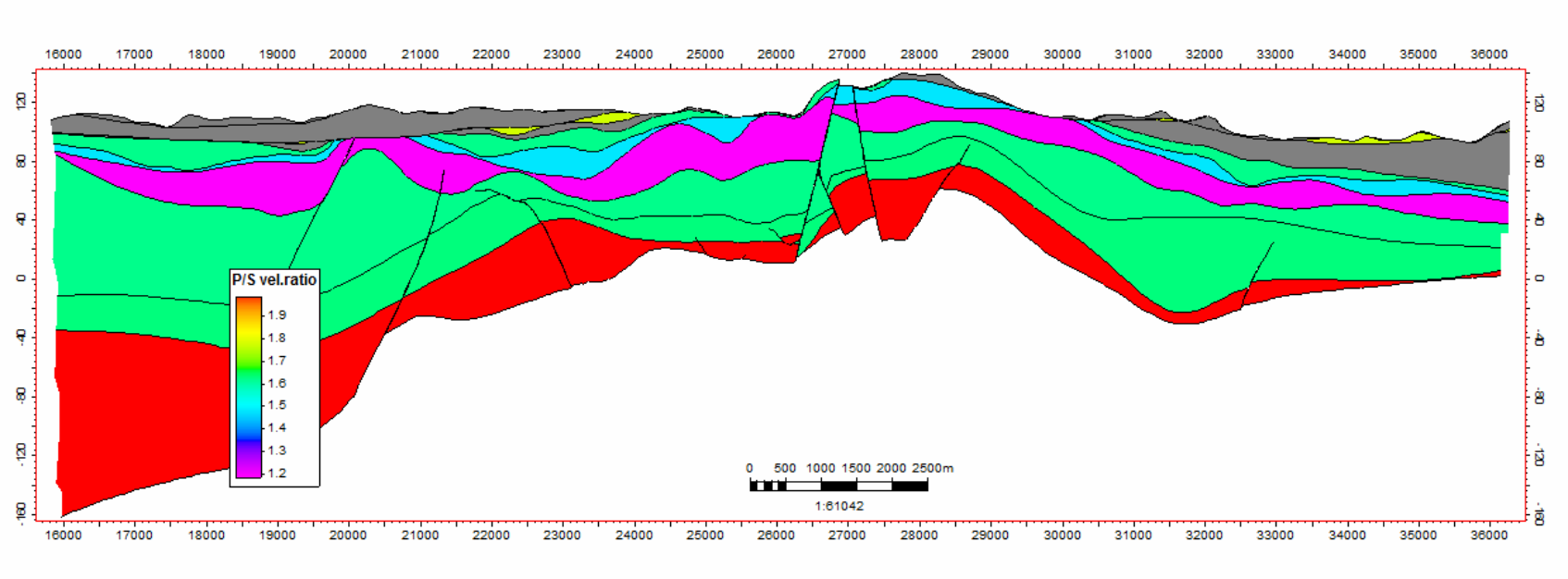
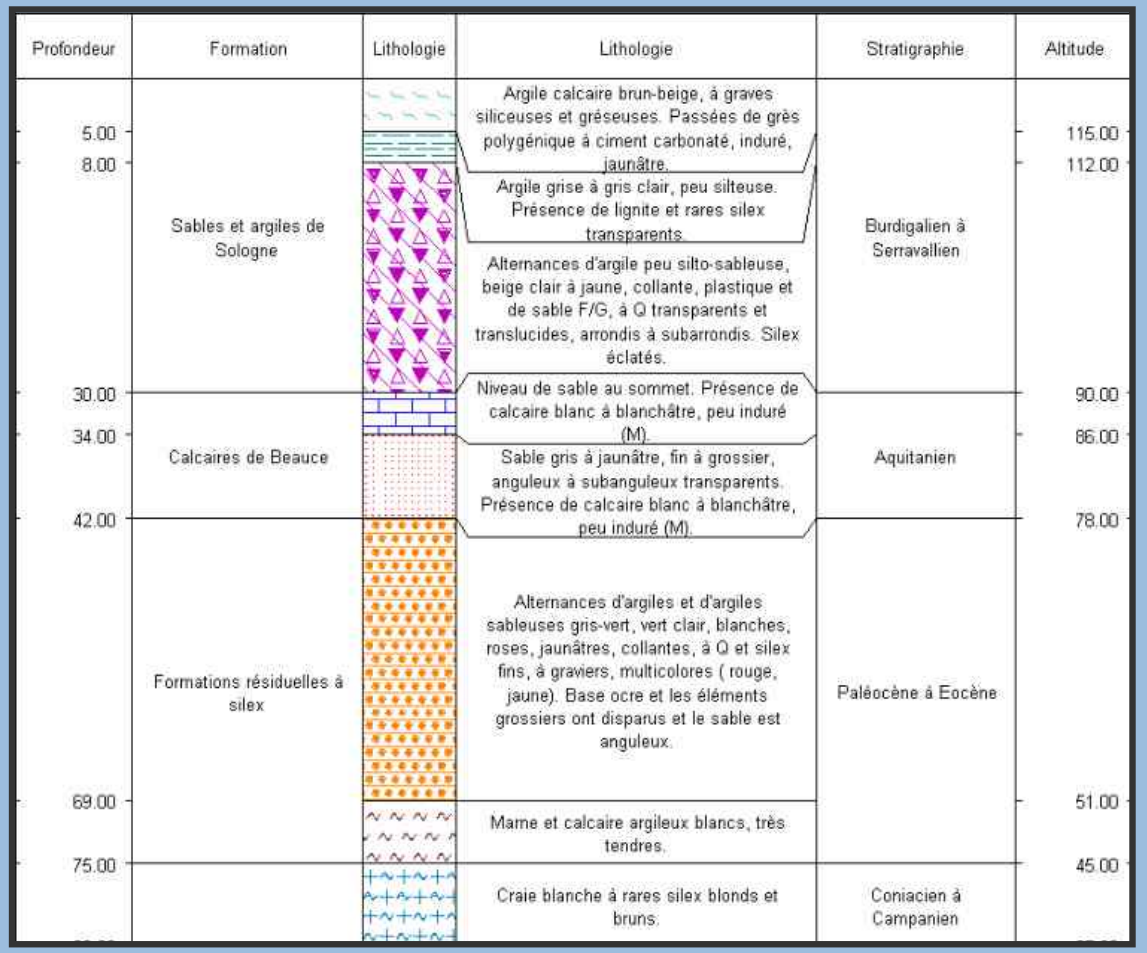
> Thanks for your attention

Vp-Vs ratio application to the well-derived model



BRGM data – lithology logs

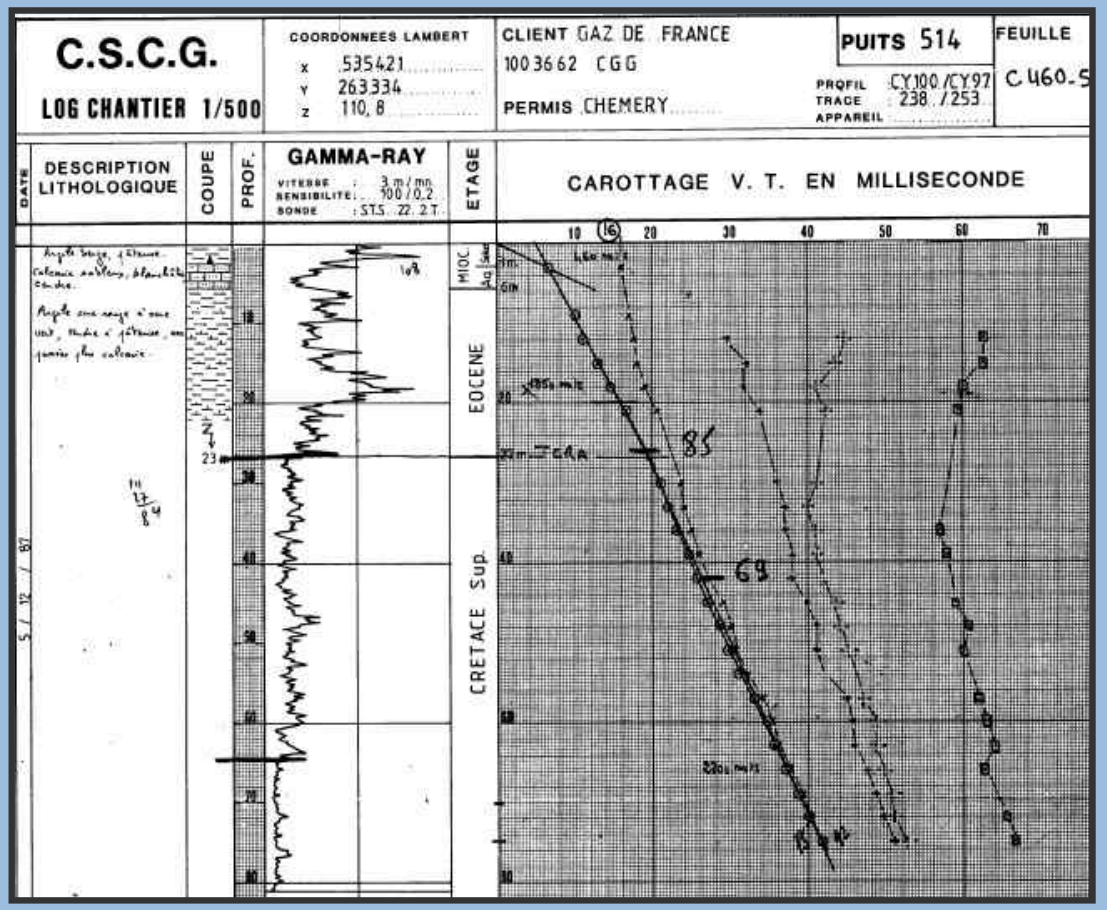
- 400 shallow wells
- Detailed lithology description and stratigraphy



Profondeur	Formation	Lithologie	Lithologie	Stratigraphie	Altitude
5.00	Sables et argiles de Sologne		Argile calcaire brun-beige, à graves siliceuses et gréseuses. Passées de grès polygénique à ciment carbonaté, induré, jaunâtre.	Burdigalien à Serravallien	115.00
8.00			Argile grise à gris clair, peu silteuse. Présence de lignite et rares silex transparents.		112.00
			Alternances d'argile peu silto-sableuse, beige clair à jaune, collante, plastique et de sable F/G, à Q transparents et translucides, arrondis à subarrondis. Silex éclatés.		
30.00			Niveau de sable au sommet. Présence de calcaire blanc à blanchâtre, peu induré (M).		90.00
34.00	Calcaires de Beauce		Sable gris à jaunâtre, fin à grossier, anguleux à subanguleux transparents. Présence de calcaire blanc à blanchâtre, peu induré (M).	Aquitanien	86.00
42.00	Formations résiduelles à silex		Alternances d'argiles et d'argiles sableuses gris-vert, vert clair, blanches, roses, jaunâtres, collantes, à Q et silex fins, à graviers, multicolores (rouge, jaune). Base ocre et les éléments grossiers ont disparus et le sable est anguleux.	Paléocène à Eocène	78.00
69.00			Marne et calcaire argileux blancs, très tendres.		51.00
75.00			Craie blanche à rares silex blonds et bruns.	Coniacien à Campanien	45.00

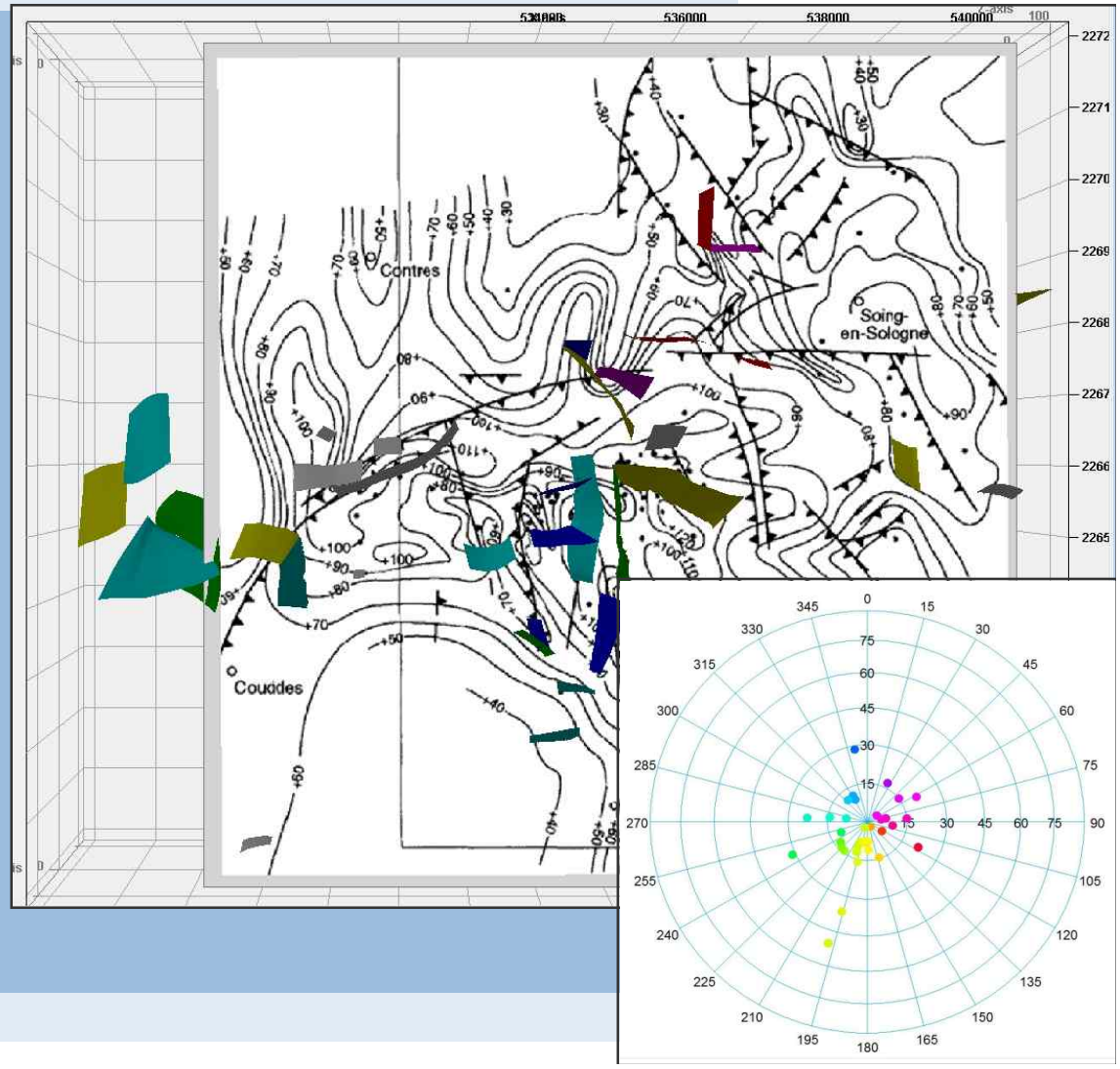
BRGM data – velocity logs

- 160 logs
- Carottage VT or Uphole surveys:
  - Borehole shooting at different depths to obtain velocity of superficial formations
  - Calculation of arrival time at the surface
  - Vp measurements

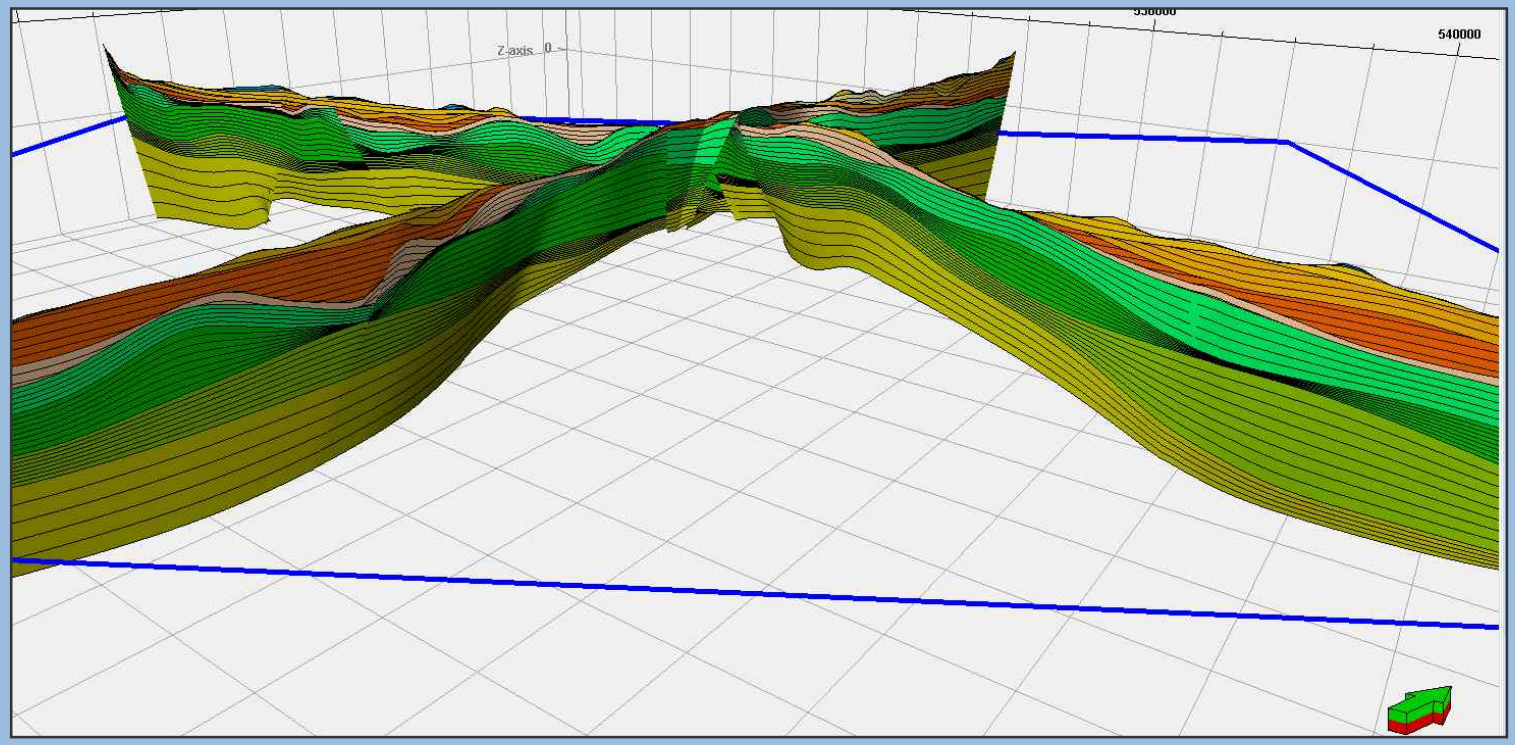


Fault interpretation check

- Comparison with old publicly available data from the deep subsurface
- Stereonet analysis
  - Mostly low angle faults
  - N-S and W-E trends



3D grid definition: layering



Geostatistical analysis

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- Variogram map to find the appropriate principal axis for defining the anisotropic variogram model
- Gridding algorithms:
  - Kriging
  - Sequential Gaussian Simulation