HARD CONDITIONING DATA
The Roussillon Plain

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Contents

1 Generality

Hard conditioning data set plays a central part in MPS simulation and geostatistical methods since they are used to constrain the simulation on the location where the value that is aimed to be inferred is already known. These data generally came from interpreted logs, geophysics data or other sources of information that can help to constrain the simulation. Regarding the Roussillon's Plain the hard conditioning data set came from lithological and geophysical logs onshore and from interpreted geophysical cross-section offshore.

The aim of this short paper is to briefly resume some important definitions and to present the different conditioning data set of the Roussillon's Plain.

1.1 Definitions

- **Lithological logs :** They are realized by the driller in charge of the realization of the borehole, or by the geologist assigned to the project. Their qualities depend on the presence of recognizable sedimentary environment indicators such as clay layer, presence of shells in the deposit or lignite/-turf deposit. In hydrogeology the realization of borehole is often realized by destructive techniques that cannot be considered as an accurate source of information. The lithological logs can informed on the type of sediment encountered at a certain depth (sand, gravel or clay) and can be interpreted as qualitative information, however, they cannot be used to infer the sedimentological facies of the deposit.

- **Geophysical logs :** Geophysical logging techniques record the physical and chemical properties of the soil. Contrary to lithological logs, the geophysical logs offer quantitative measurements that can be interpreted as sedimentological facies and deposit sequences. In hydrogeology the most frequent geophysical logging are the **Gamma-ray**, the **Resistivity** and sometimes the **Spontaneous polarisation**.

- **Gamma-ray (GR) :** GR logging measures the natural radioactivity of the rocks/soils produced by the 3 major radioactive elements that are the Potassium (K), the Thorium (Th) and the Uranium (U). The Potassium (feldspath or mica) and Thorium (zircon, tourmaline, rutile) are mostly found in clay deposits. The Uranium is mainly presented in organic mater (shell and vegetable sediments) and characterizes the presence of clay in reducing environment. Gamma-ray measures are directly correlated to the clay content of the sediment and its value generally increases with the decrease of the grain size of the sediments (Fig 1). It has to be noted that a fluvial channel rich in potassium feldspath could produce a similar gamma-ray response as a rich clay contend environment and therefore the interpretation of gamma-ray is usually coupled to resistivity curves analysis to avoid error in the facies interpretation.

- **Resistivity (Res) :** Res logging measures the electric or magnetic signal response of a material. The resistivity depends on, the percentage of water presents in the material and on the water's resistivity (an increased in dissolved minerals yield to a decreased of the resistivity), on the clay content (percentage of conductive materials, clay are less resistive than gravel and sand) and on the internal arrangement of the material (distribution of the pores).

- **Spontaneous polarisation (SP) :** SP logging records the potential difference between a moving electrode and the electrochemical signal of the soil. The signal is positive when the electrode faces clay sediments (cations (+) are moving towards the electrode which is the less saturated) and is negative when the electrode faces permeable units such as sand (Cl- anions (-) are moving towards the electrode which is still less saturated).

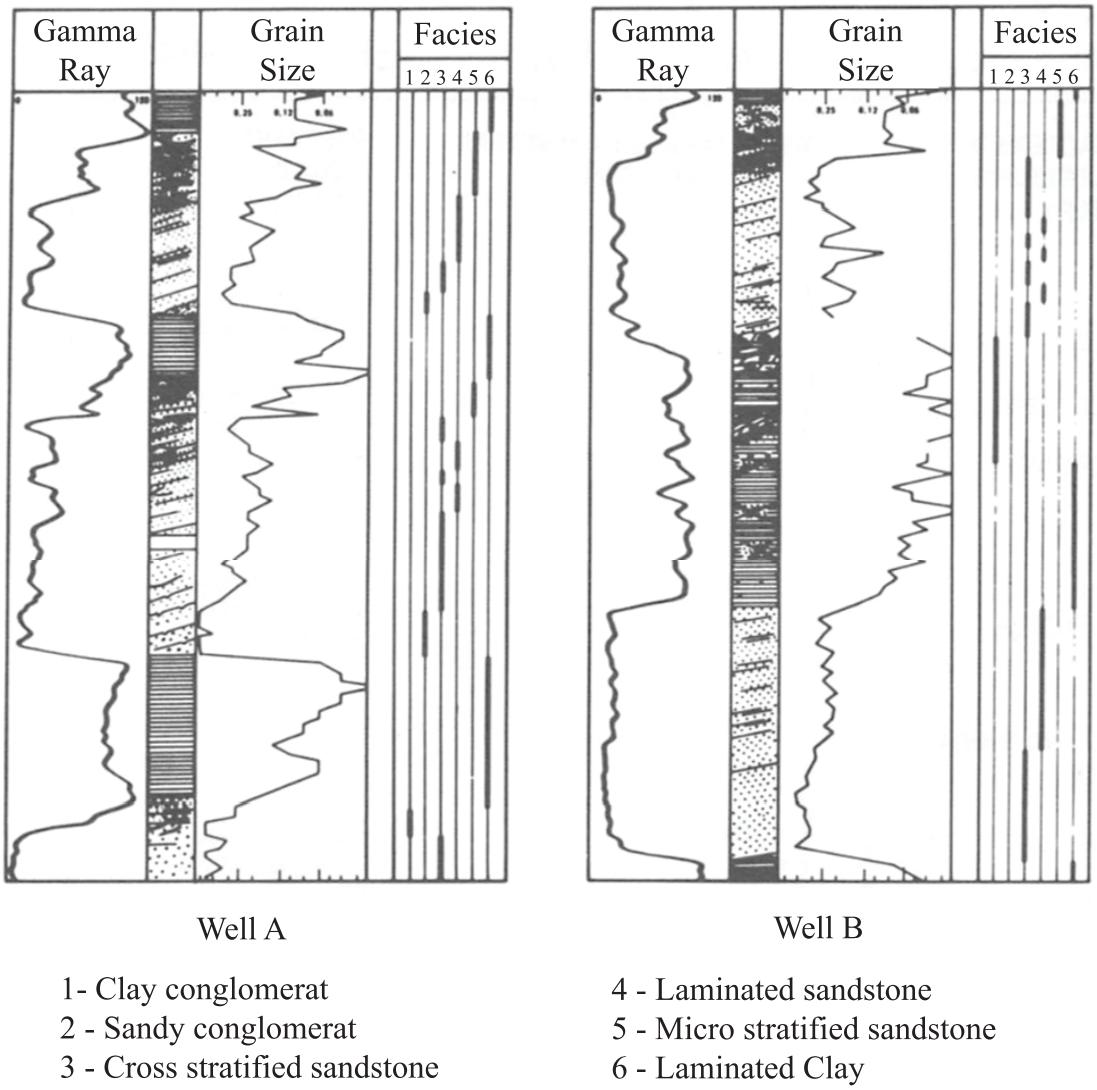


Figure 1: Correlation between natural radioactivity and grain size distribution of sediment (modified from Sierra and Sulpice 1975, 1985).

1.2 Geophysical logs interpretation

Geophysical logs data can be interpreted in terms of sedimentary facies. During the interpretation, it is not only the measured value of resistivity or gamma-ray response that is determinant to the characterization of the facies but also the couple vertical evolution of these two curves. To facilitate the interpretation the gamma-ray curve is usually presented on the left of the resistivity curve. Figure 2 presents response curves for gamma-ray and resistivity logging and compares them to two sequences of deposition.

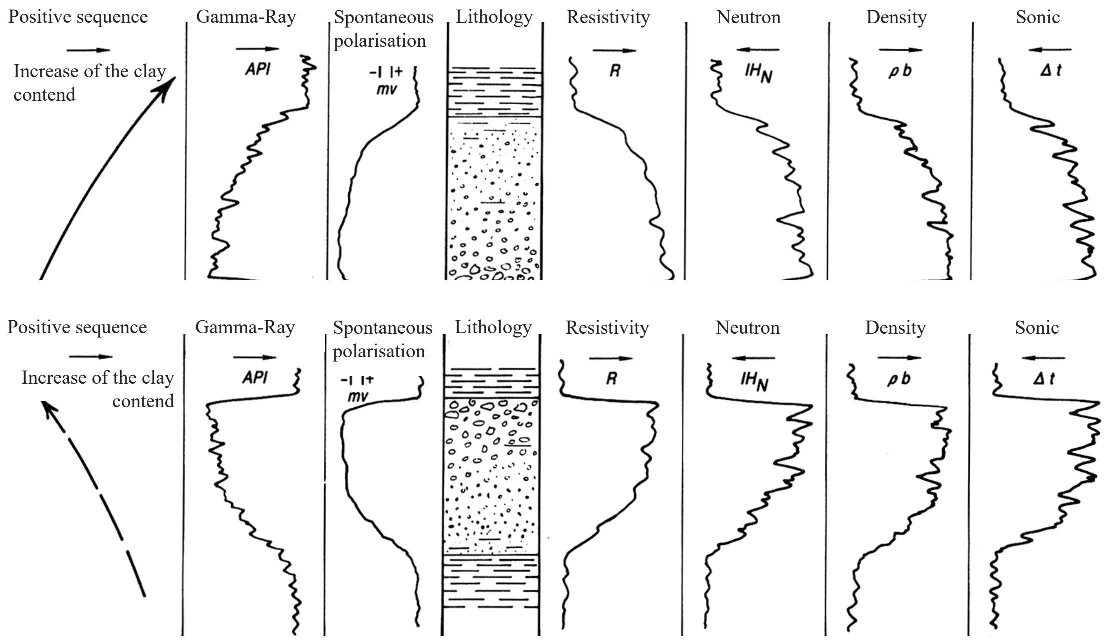


Figure 2: Response curves for two different sedimentation sequences. The curves have to be interpreted jointly in order to avoid facies misinterpretation.

In his thesis, Duvail presents a description and an interpretation of the response curves for the different facies composing the Pliocene's aquifer. Theses descriptions are presented in figure 3 and figure 4 in simplified versions. Figure 3 presents the facies composing the alluvial environment; the alluvial channel, the flood plain, the wetland deposit and the proximal part of Gilbert delta. The second figure (Fig 4) corresponds to the marine facies of the Pliocene.

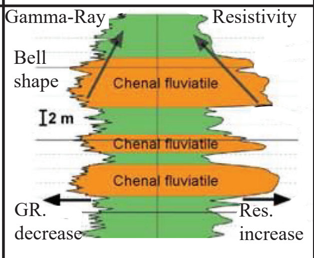
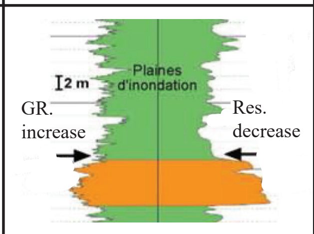
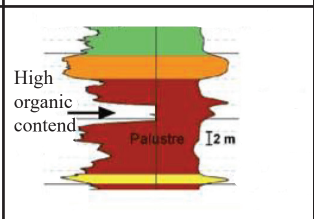
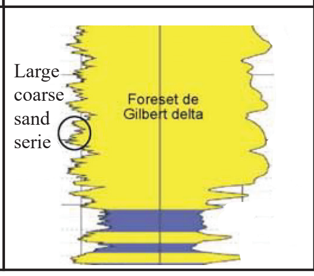
Facies Name	Geophysical logs	Grain size description	Depositional environment
Alluvial channel		Gravel sand, coarse to medium sand	Alluvial channels, braided river network is dominating
Flood plain		Clay and sandy clay	Clay from flood plain and sand from old crevasse splay and levee deposit
Wetland deposit		Very variable, from gravel to clay or marl	Swamp and lagoon environment
Sandy marine deposit (dominated by alluvial deposit)		Coarse gravel and sand	Gilbert delta foreset

Figure 3: Facies interpretation of the Pliocene's sediments interpreted from GR and Res curves (modified from Duvail 2008).

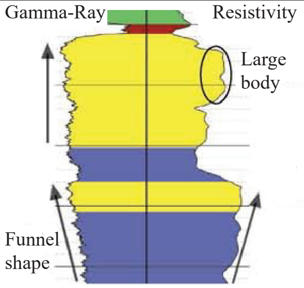
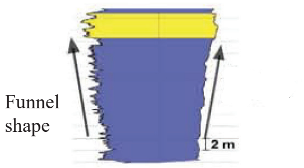
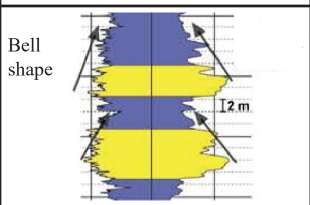
Facies Name	Geophysical logs	Grain size description	Depositional environment
Sandy Marine / littoral deposit		Gravel sand to sandy clay	Deltaic front
		Sandy clay to fine sand to silt	Deltaic plateform
Clay Marine deposit		Clay or marl to sandy clay	Pro-delta
Gravity deposit		Clay and Sand	Turbidites

Figure 4: Facies interpretation of the Pliocene's sediments interpreted from GR and Res curves (modified from Duvail 2008).

1.3 The Roussillon data set

The Roussillon geological database is composed of more than $2'000$ boreholes. Duvail has described than only 200 wells reach a depth superior of 100m. Moreover, over the database only 90(to update) wells are described by geophysical logs, while the rest of it is only described with lithological logs.

Regarding the onshore Continental Pliocene (PC), the hard conditioning data set is composed of interpreted borehole logs (gamma-ray and resistivity logs) and geological data extracted from the Roussillon's geological map. Once interpreted, the total hard data set is composed of more than 3500 points, which are used to constrain the MPS simulation.

The next section presents first the hard conditioning data set created from the interpretation of geophysical logs. The following section presents the hard conditioning data set created from the geological map.

The offshore data integration will be discussed and described soon and will be added to this document.

2 Wells data set

The first part of the hard conditioning data set is composed of 90 (to update) boreholes logs. Each one of these is characterized by a gamma-ray and/orresistivity curves, which can be interpreted in term of sedimentological facies. The interpretation takes place in the Petrel software.

The different steps for the creation of the well hard data set are the following:

1. Vectorization of the .pdf or .ai log files, using Neuralog (**input**: .jpeg or .tiff, **output**: las):
   - Transform the .pdf or .ai file to .jpeg or .tiff format.
   - Define the scale of the well log.
   - Define the scale of the GR/Res curves.
   - Add scale reference lines at different depths.
   - Add a new curve to the project.
   - Save and export as a digital log (.las).
2. Interpretation with Petrel :
   - Create a wellheads file. Petrel requires a .txt file with the coordinate of the wellheads (Wellname, Id file, X, Y).
   - Import the header file to petrel (/File/import File) and define the parameter of the header.
   - Import the well logs (/File/import/well Log (.las)) and select the "import in lot" option.
   - Create a new well section and upload each well by clicking on it on the left window.
   - Create a new discrete log.
   - Assign the facies value at discrete depth location.
   - Export the wells (/Wells/export all well in folder).

3. Creation of the hard data set from Petrel to point set:
    - Collect the facies information from the different output file (python code).
    - Transform the depths of the point set according to the altitude of the wellheads.
    - Transform the depths of the point set according to the transformed altitude of the grid (python code).

This interpretation process was executed two times in order to create two different point sets, one representing a 3 facies model and the other one representing a 5 facies model (Fig 5).

a)

Interpretation	Facies	Code	Color
Simple	Flood plain	0	
	Alluvial channel	1	
	Alluvial fan	2	
Complex	Flood plain	0	
	Braided river	1	
	Meander river	2	
	Crevasse splay	3	
	Alluvial fan	4	

b)

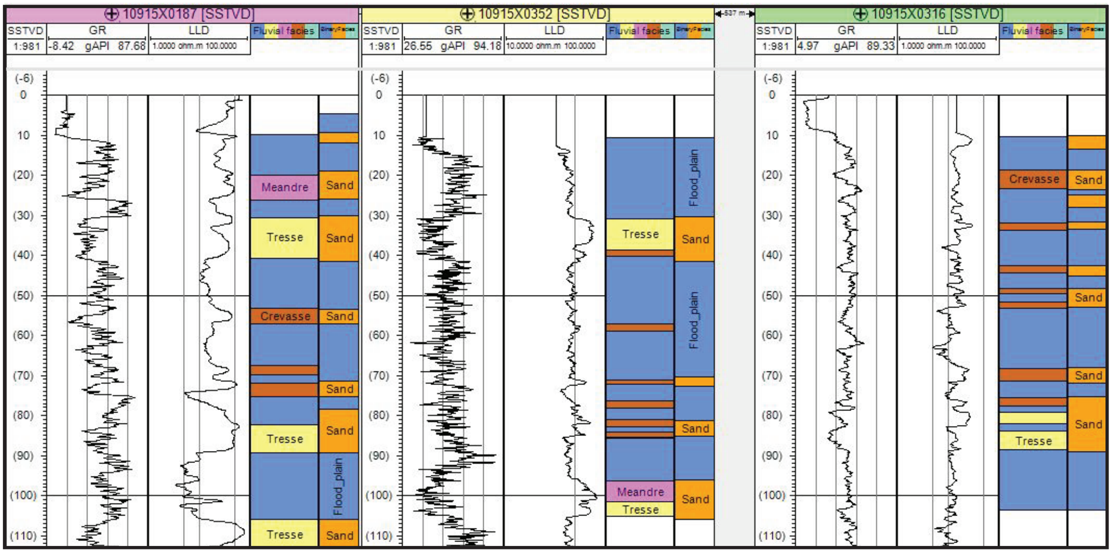


Figure 5: Facies interpretation of the Roussillon data set. a) two approaches have been carried out, one with 3 facies and one more complex with 5 facies. b) example of facies interpretation, the left column corresponds to the complex model and the right one to the simple model.

3 Geological data set

The second hard conditioning data set is created based on the Roussillon's geological map. Since the Continental Pliocene layer is exposed and mapped, the model has to honor this information. By creating and using a dense hard conditioning data set created from the geological units of the exposed PC, the MPS model will respect the geological information during the simulation.

The geological point set is created using QGIS. The different steps are the following:

1. Import the geological map of the Roussillon.
2. Extract the Pliocene units.
3. Extract the alluvial fans units.
4. Transform the corresponding shape-file to point set.
5. Extract the altitude of the points from the DEM of the plain.
6. Export to .csv.
7. Transform altitude according to the transformed grid (python code).

The final geological hard conditioning data set is composed of 1448 points. This set only describes exposed alluvial fan facies. (Fig 6).

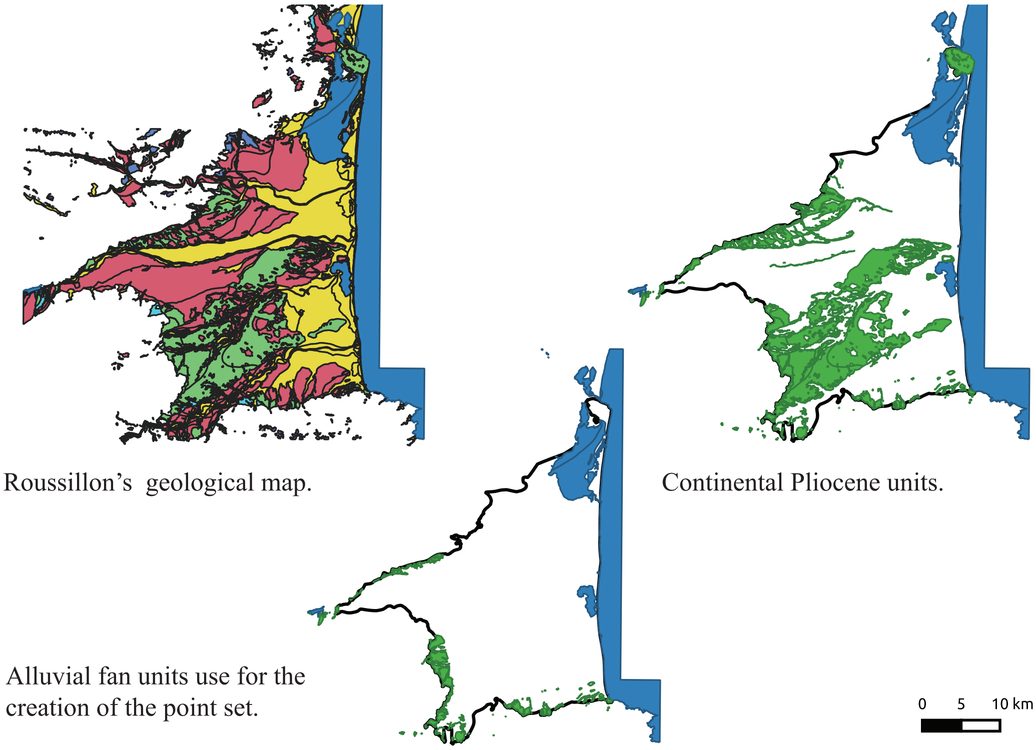


Figure 6: The geological hard data set is created from the Roussillon geological map, where the alluvial Pliocene units are isolated and transformed to point set.