3D facies modelling strategies in large fan-delta reservoirs and their implications in predictions. Data from Montserrat and Sant Llorenç del Munt outcropping analogues (Eocene, NE Spain)

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INTRODUCTION

During the last decades, 3D models of subsurface geological heterogeneity have proved to be important tools for the efficient management of hydrocarbon reservoirs.

Previous works modelled facies belt distribution in the Sant Llorenç del Munt complex at production scale based on outcrop data (Cabello *et al.* 2010). In the present work, a new outcrop-based exploration scale 3D facies model including the production scale model area is presented.

The total area comprises both Montserrat and Sant Llorenç del Munt fan-delta complexes developed during the Eocene in the South Eastern Ebro basin.

This margin was controlled by transpressive tectonic activity generating thrusts and folds in the Prelitoral range.

Depositional stratigraphic record of these fan deltas has been described as mad up by several transgressive to regressive composite sequences each defined by the stacking of several high-frequency fundamental sequences.

Stratigraphically the model includes the record of three composite sequences, representing a stratigraphic thickness of 325 meters, and it covers an area of 375 km3 and it covers an area.

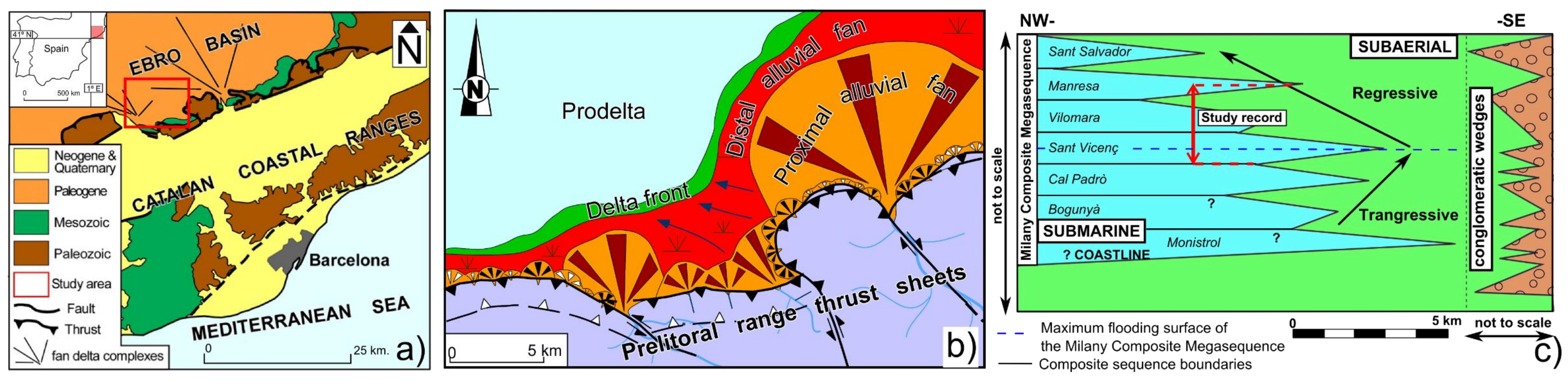

Figure. 1. *Geological setting of the study area.* ***a)*** *Location of Montserrat and Sant Llorenç del Munt Eocene fan-delta complexes (Eastern Ebro Basin, Spain),* ***b)*** *Paleogeographic map representing facies distribution (modified from López-Blanco et al., 2000),* ***c)*** *Stacking pattern of the whole Milany Composite Megasequence, made up by seven composite sequences (modified from López-Blanco et al., 2000). The modelled record is indicated. It includes: the Sant Vicenç, Vilomara and Manresa (until its maximum flooding surface) composite sequences.*

METHOD

<u>**Input data**</u>: Eight geological maps at scale 1:10.000 (López-Blanco & Piña 1992/93), georeferenced digital terrain models (5m x 5m of resolution) and ortophotographs (pixel size of 25 cm) by the *Institut Cartogràfic de Catalunya*.

1) Horizon framework & fault modelling: Digitization of the key surface traces onto the photorealistic terrain models; these surfaces are those bounding transgressive and regressive sequence set of composite sequences **(Fig. 1b)**. The derived altitudes were used to elaborate contour maps of each key surface. Those maps and also the reconstruction of nine vertical faults and two thrusts, were the base for the 3D reconstruction of the structural framework **(Fig. 2)**.

2) 3D Gridding: The 3D volume delimited by the key stratigraphic horizons and faults was gridded in 7,5 million of cells. Cells dimensions were 100m x 100m (faces oriented following the main paleocurrent direction (i.e. 320º), and a proportional layering was selected with a mean cell thickness of 1.75 m **(Fig. 2b)**.

3) Facies modelling: Aimed to reproduce the stratigraphic distribution of the main facies belts which are present in the fan-delta complexes (thrust-related alluvial breccias, proximal alluvial fan, distal alluvial fan, delta front, carbonate platform and prodelta) **(Figs. 3c, 5 and 7)**. Terrigenous facies belts were reproduced using TTG (Truncated of the sum of a deterministic expectation Trend and a Gaussian random field; MacDonald & Asen 1994).

This process was guided by the elaboration of several paleogeographic maps **(Fig. 3a)**. The Gaussian stochastic part of the algorithm was used to reproduce the interfingering between different facies belts showing more detailed scale of geological heterogeneity. The carbonate platforms were assimilated as ellipse-shape geobodies and reconstructed using an object based algorithm. Its distribution was fixed depending on the nature of the sequence (40% of volume in transgressive and 10% in regressive), and determined to vary vertically. Finally its position was constrained to be within the distal delta front and proximal prodelta.

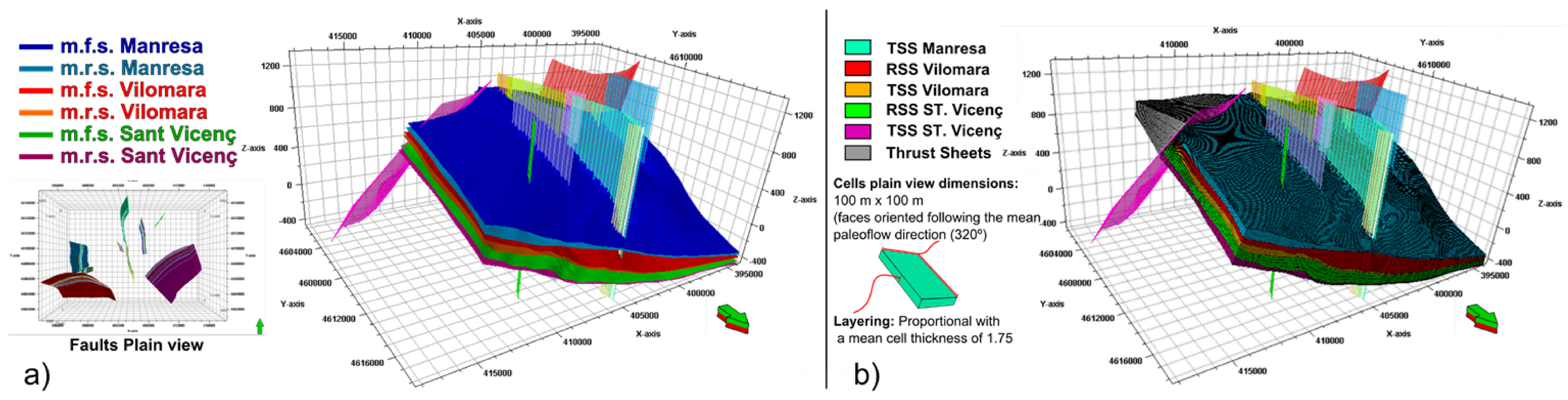

Figure 2. a) *Structural framework of the 3D model including the reconstruction of the key stratigraphic horizons (i.e. surfaces bounding transgressive and regressive sequence sets at scale of composite sequences), the vertical faults and the thrusts associated to the basin margin.* ***b)*** *3D Grid between key horizons.* ***m.f.s.:*** *maximum flooding surface,* ***m.r.s.*** *maximum regressive surface, TSS: Transgressive Sequence Set, RSS: Regressive Sequence Set.*

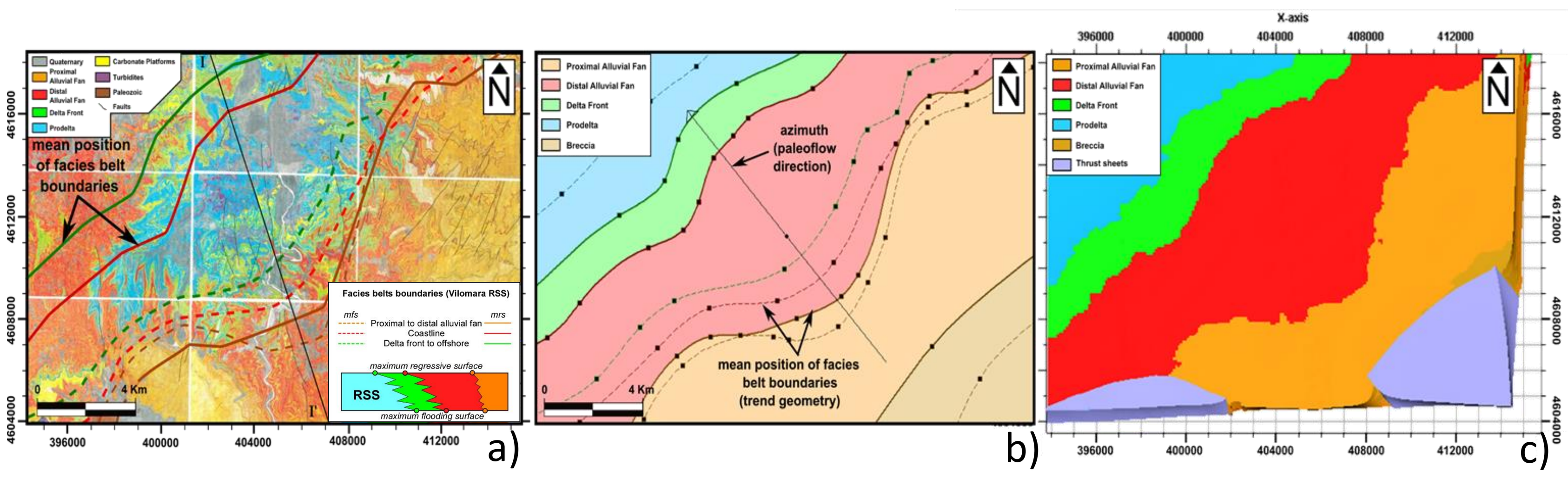

Figure 3. a) *Paleogeographic maps showing facies belt boundaries position (proximal to distal alluvial fan, coast line and delta front to offshore boundaries) just below and above the key stratigraphic surfaces (Vilomara maximum flooding surface in this case). Its elaboration was done by using detailed field maps.* ***b)*** *Definition of the geometry and position of the deterministic trend of the TTG algorithm using the paleogeographic maps.* ***c)*** *Top view of the final 3D facies model. Coordinates are in Universal Transverse Mercator (UTM) zone 31. Vertical exaggeration is 6x.*

RESULTS

The exploration scale facies model (375 km^2 and 325 m thick) of two outcropping fan-delta complexes satisfactorily captures the heterogeneity linked to the T-R cyclicity at two scales (composite and fundamental sequence scale) **(Figs. 5, 6 and 7)**, and thus the modelling strategy could be applicable in the subsurface.

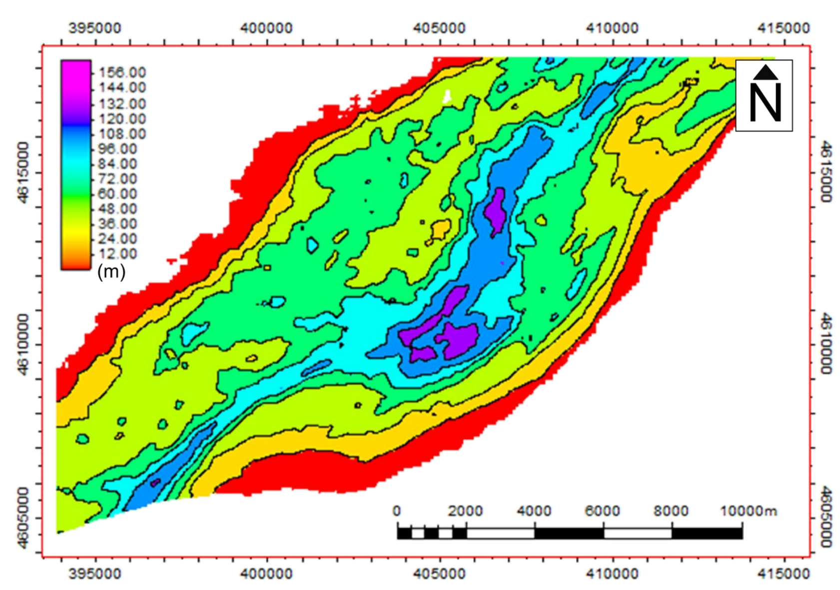

Figure 4. *True stratigraphic thickness map of the delta front facies obtained from one realization. Coordinates are in Universal Transverse Mercator (UTM) zone 31.*

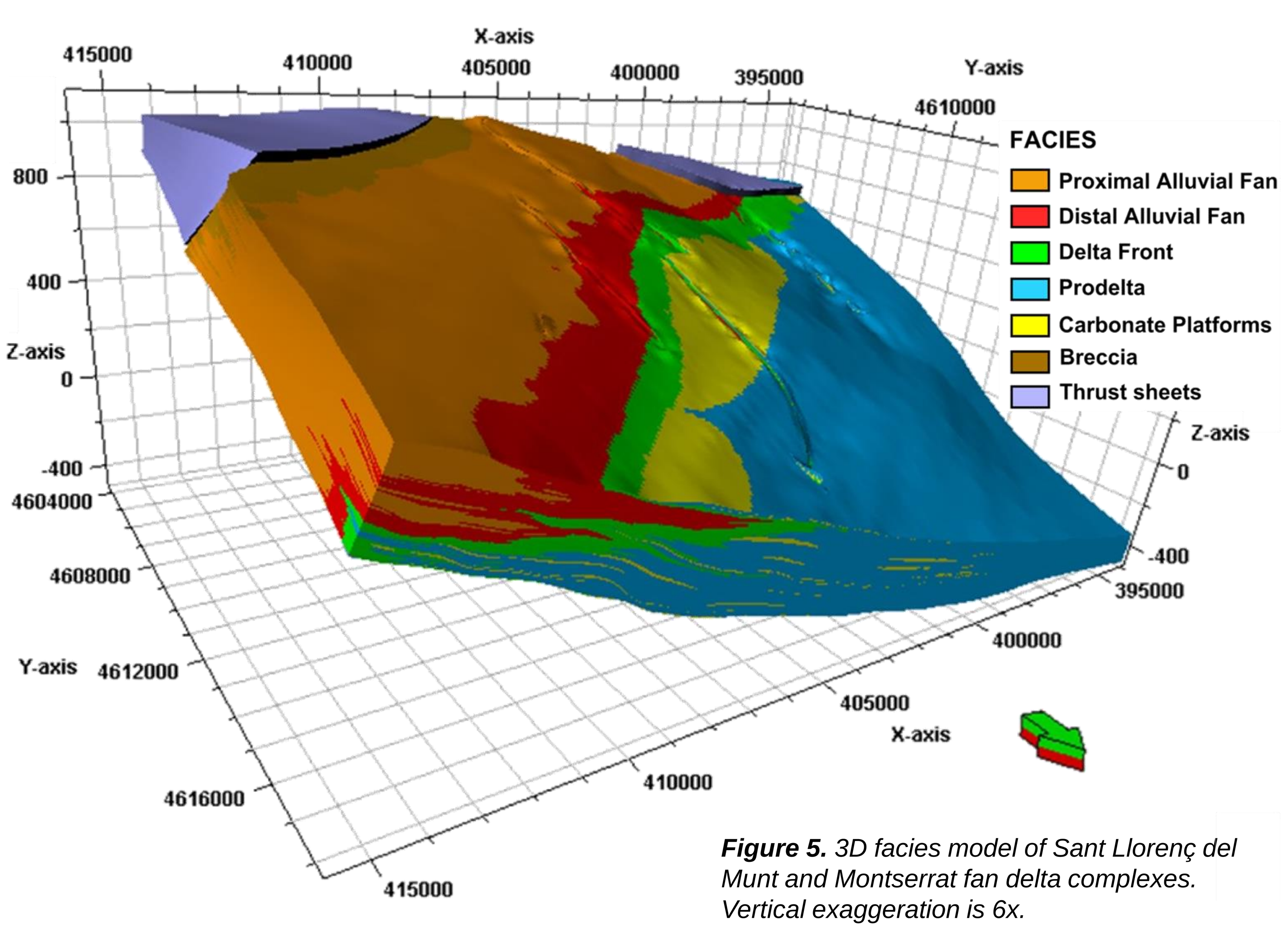

Figure 5. *3D facies model of Sant Llorenç del Munt and Montserrat fan delta complexes. Vertical exaggeration is 6x.*

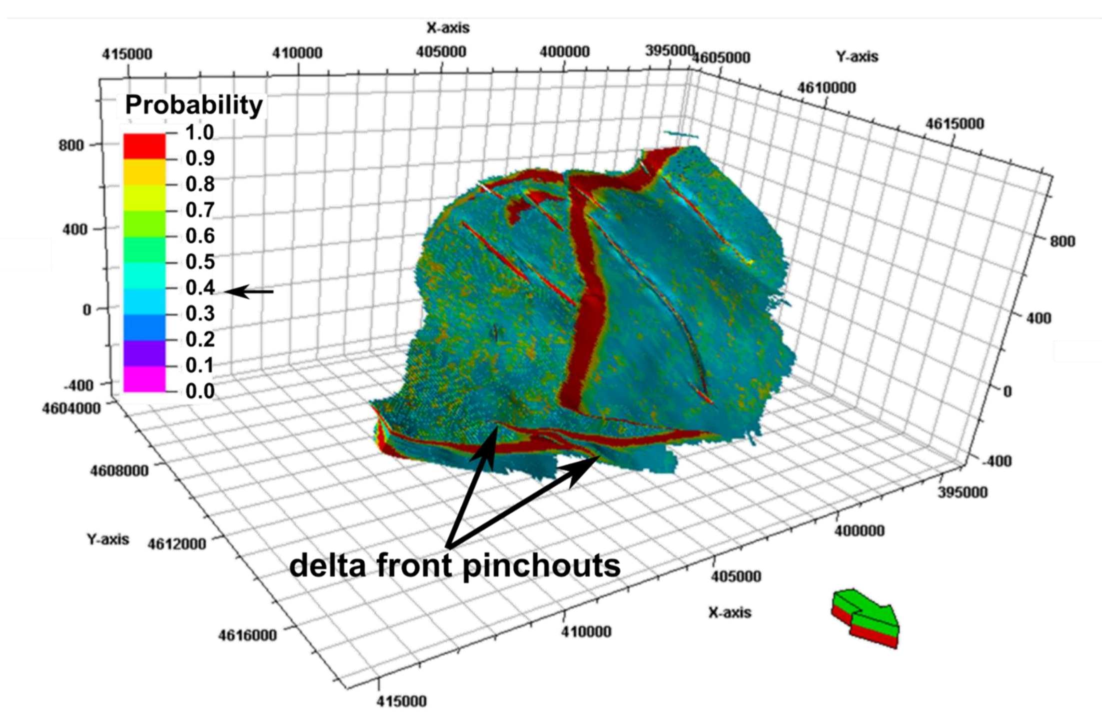

Figure 6*. Probability of finding delta front facies averaged from the 10 realizations of the 3D facies model (values filtered between 0.3 and 1- maximum probability). Coordinates are in Universal Transverse Mercator (UTM) zone 31. Vertical exaggeration is 6x.*

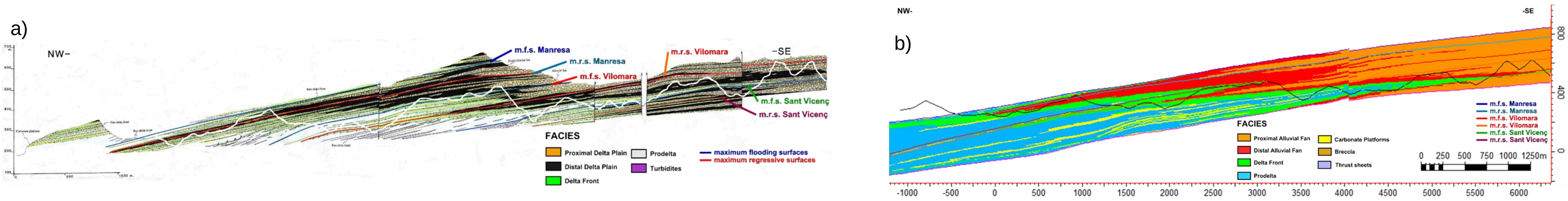

Figure 7. a) *Riera de la Santa Creu Cross section, (López-Blanco, 1996),* ***b)*** *SE-NW oriented cross-section from the model at the same transect as* ***Fig. 7a****. Notice the high correlation between both cross sections.*

CONCLUSIONS

- The architecture and distribution of fan-delta front reservoir analogue rock can be documented from the model.
- The model reproduces a continuous delta front facies belt connected along the different sequences **(Fig. 7b)**.
- Fan-delta front facies maps extracted from the model shows maximum accumulated vertical thicknesses of about 135 m, preferentially concentrated in the central part of the study area following a trend parallel to paleocoastline **(Fig. 4)**.
- Its complex geometry could also capture the existence of potential stratigraphic traps related to the endings of fan-delta front wedges into prodelta and distal alluvial mudstones resulting from the T-R cycles at composite sequence scale **(Figs. 5 and 6)**.

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