A new code for modelling hierarchical stacking patterns in deep-water lobes

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1. Introduction

As a crucial oil exploration target, deep-water lobe systems are usually linked to a high degree of uncertainty due to their inaccessibility. Therefore the generation of accurate and realistic geological models of these systems is crucial. Based on the approach of Pyrcz et al. (2005a, 2005b), a code that merges stochastic object-based and rule modelling has been created in order to advance the understanding of deep-water modelling.

2. The algorithm and the rules

The main objective of the models is to mimic realistic stacking patterns and erosion at different hierarchical levels in deep-water lobes whilst maintaining algorithmic efficiency. This can be achieved through rule based modelling, where lobes will follow previously-defined rules. The three main rules of the code are (1) the rule of hierarchy, (2) the deposition rule and (3) the erosion process (figure 1A). More refined but less fundamental rules are also included in the modelling, but this poster focuses on the previously mentioned ones.

Hierarchy

The hierarchical scheme of Prelat et al. (2010) is used in this work. It divides deep water lobes into a four fold hierarchy, in which smaller components stack and form larger ones. From smaller to larger, the components can be divided into bed to bed set, lobe element, lobe and lobe complex. The code defines larger hierarchies as a container, which will act as a constrain for the smaller components (figure 1B, C).

Deposition

After every deposition event, a probability distribution function (PDF) is computed. This controls where the maximum thickness of the next deposit will be located. This approach makes it possible to generate a continuum between completely compensational systems (lobes will look for topographic lows, figure 1D) and totally random ones. For every lobe, a shale cover can be deposited above it.

Erosion

Before the deposition of the objects, the code checks if they will erode the underlying ones (figure 1E). It is important to note that erosion does not mean amalgamation. If erosion is weak, it will only erode a portion of the shale and not generate inter-element connectivity.

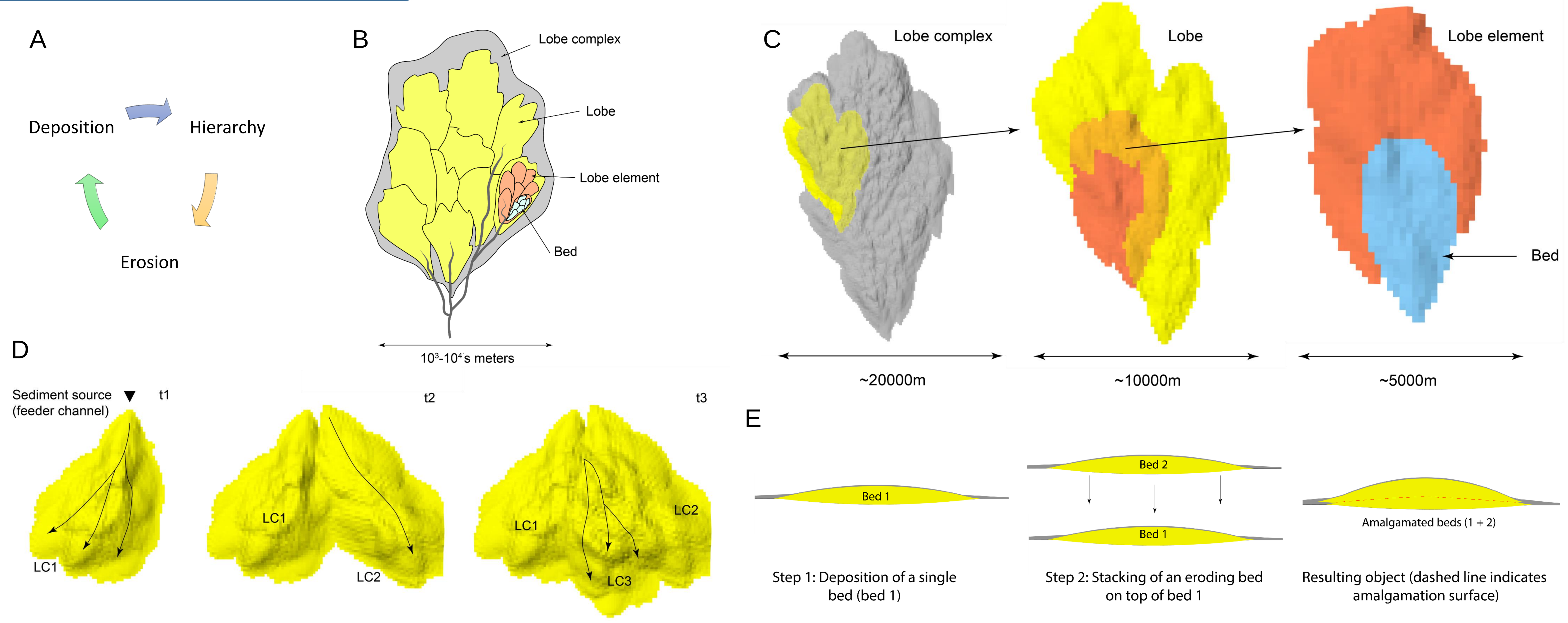

Figure 1. A) Rules applied for building the model. None of them is independent, as they are directly related to each one. Hierarchy will control the erosion extent and deposition, and at the same time deposition will be influenced by erosional surfaces and will control the next hierarchical levels. B) Hierarchical scheme (modified from Prelat, et al 2010) and a modelled hierarchical lobe (C), where the smaller elements have ben highlighted. Each hierarchical level is constrained to its previous larger hierarchical container. D) depositional sequence through t1 to t3 of three lobe complexes (LC). Note how they avoid to be deposited above the previous ones. E) Schematic process of erosion leading to amalgamation between two beds.

Two different lobe systems have been generated. They consist of 5 lobe complexes, 20 lobes, 100 lobe elements and 600 beds. Both have the same input, and are "forced" to be completely compensational, but the seafloor geometry is different. Case 1 corresponds to an unconfined while case 2 links to a confined system. Erosion was set at a 35% probability: successive events have that probability of eroding the underlying deposits. To ensure the generation of amalgamation surfaces and removal of inter-element shale layers, the deposits that erode can do it up to a 30% of their own thickness.

3. Case 1: unconfined system

A good example of an unconfined deep-water system is the Permian basin floor fan system in the Tanqua-Karoo area (South Africa, Prelat, et al. 2010). Lobes are free to migrate laterally and compensate, since they do not have any lateral limitation. A flat bathymetry was generated, and sequentially filled with deposits with enough freedom to shift laterally. Figure 2 shows a panel of this case with the largest connected cluster (F_M = 9.58%) highlighted. Larger NTG values are located close to the source, as they gradually decrease to zero as the lobe disperses.

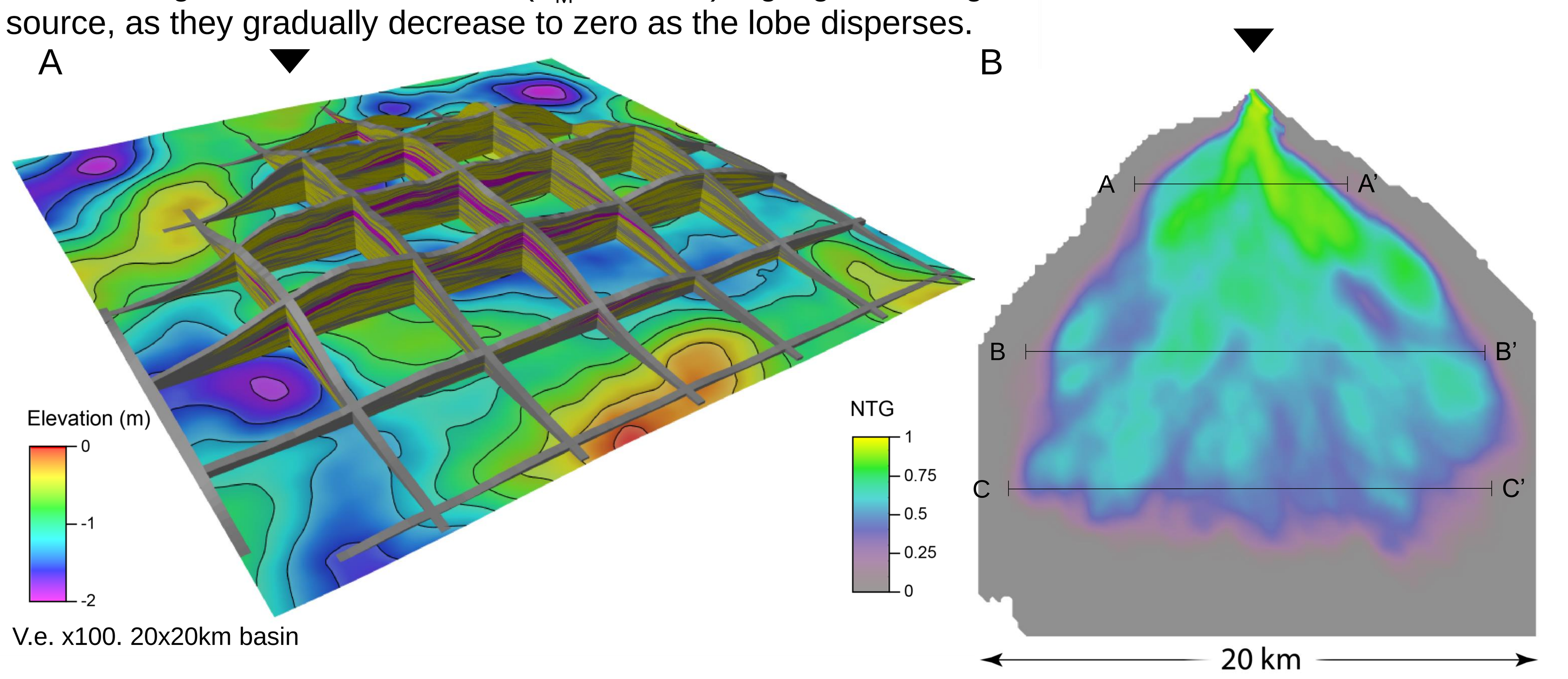

Figure 2. A) 3D Panel of 5 unconfined lobe complexes. The largest connected cluster has been highlighted. The black inverted triangle indicates sediment source. B) NTG map showing how the larger NTG values are located close to the source, decreasing uniformly as the lobe expands.

Hierarchical elements and NTG proportions can be easily observed in cross-section. Figure 3 illustrates cross-sections perpendicular to flow direction, where amalgamation surfaces, hierarchies and compensational stacking are observed. Different hierarchical levels are inter-connected, with the largest cluster highlighted. It connects the 3rd and the 5th lobe complexes and their smaller hierarchies.

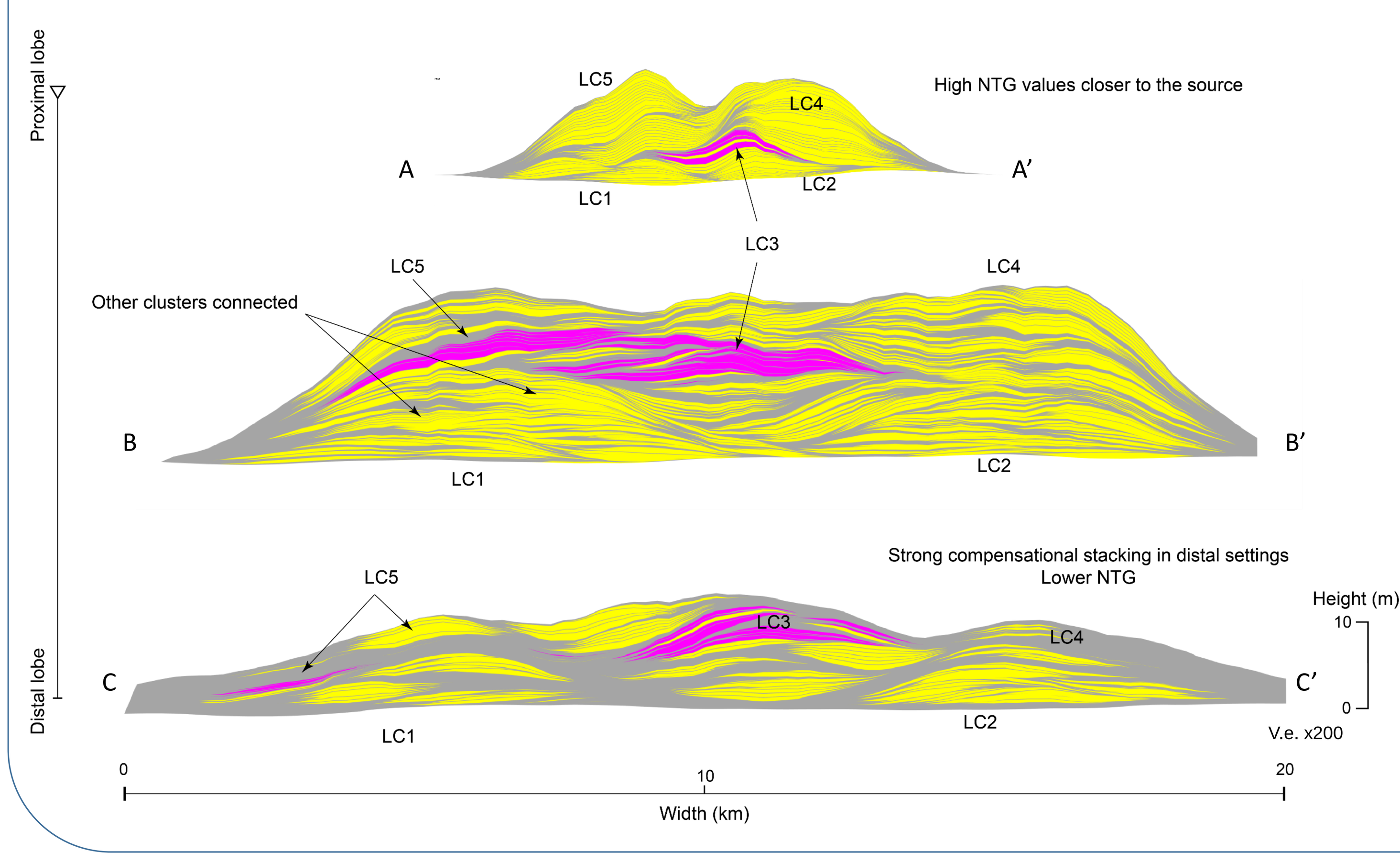

Figure 3. Three perpendicular to flow cross sections corresponding to proximal, medium and distal settings for the five Lobe Complexes (LC). Due to the space availability, hierarchical elements are easier to recognize, as well as a clear NTG trend decreasing towards distal fringe.

4. Case 2: confined system

When the accommodation space is too narrow relative to the fan system width, lobes are not able to shift laterally large distances. Due to this lack of lateral space, deep-water sheets are usually axially confined by the basin and aggrade. Lobes try to find the very limited topographic lows, producing a more vertical stacking trend. This results in high NTG values close to the source, as well as relatively high in lateral fringe and axial parts or the basin, decreasing in more distal fringe settings (figure 4).

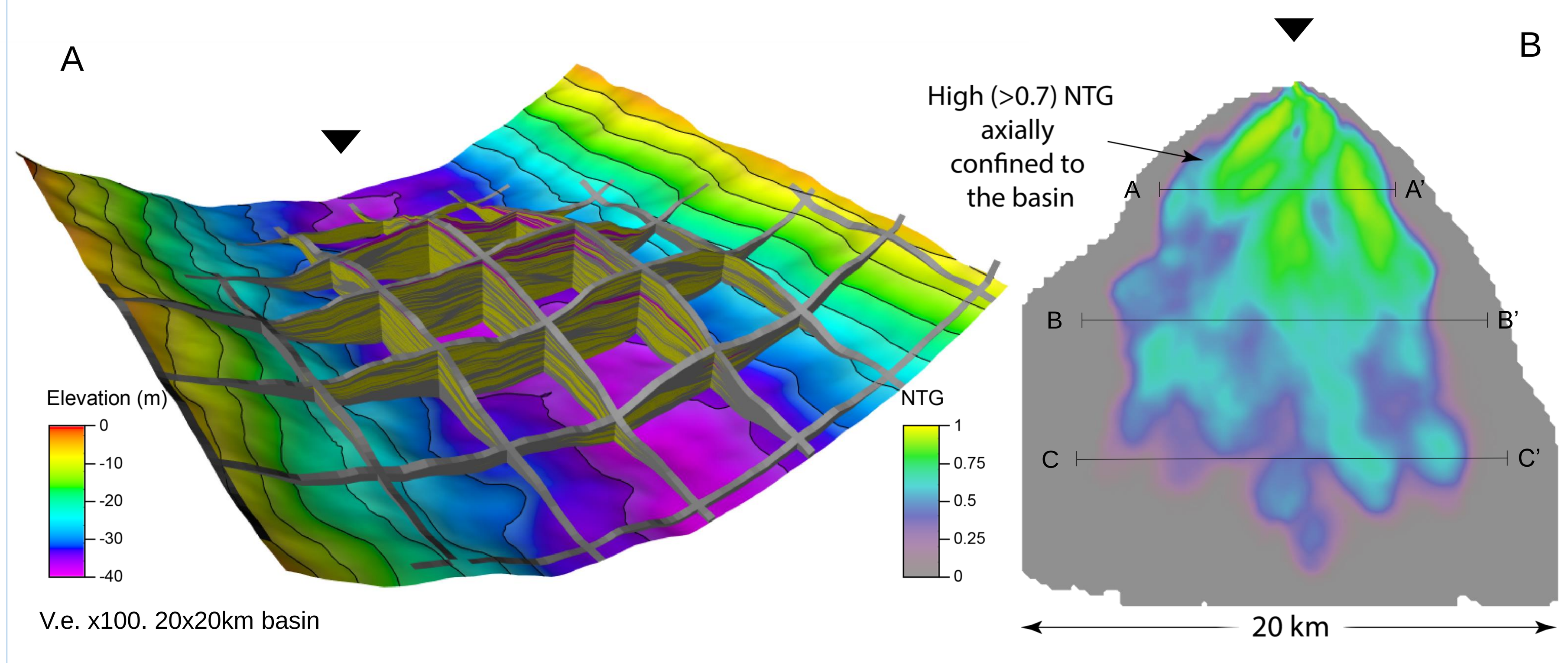

Figure 4. A) 3D Panel showing the geometrical complexity and the largest connected cluster (F_M = 7.70%). The black inverted triangle indicates sediment source. B) NTG map showing where are located the larger net:gross areas. >0.7 values are located close to the source and, due to confinement, in the axial parts of the lobe.

Figure 5 shows examples in cross-section of case 2. Hierarchical elements are harder to identify due to a more vertical stacking behaviour. Amalgamation connected two different hierarchical bodies, joining together lobe complex 4 and lobe complex 5.

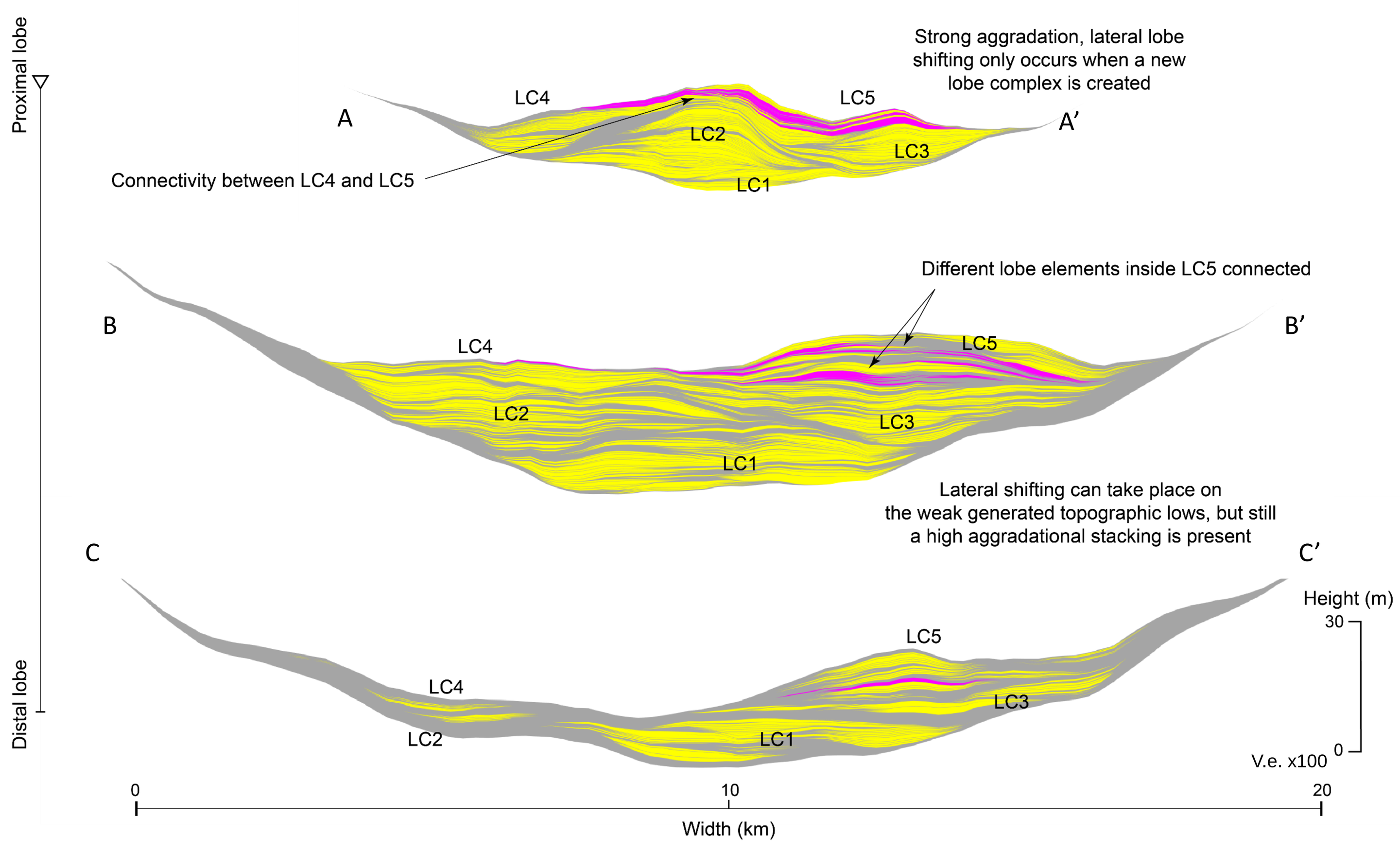

Figure 5. Three perpendicular to flow cross sections corresponding to proximal, medium and distal settings for the five Lobe Complexes (LC). Deposits are more stacked vertically than in the unconfined case.

4. Conclusion

Models are capable of reproducing complex geometries at different hierarchical scales, as well as adapt themselves to an idealised bathymetry. They show that even in confined settings, some lateral migration behaviour can be expected. Recent work has shown that real-world bathymetry is also possible to implement.

More rules will be added. A priority is to have a better control on the volume of the lobes and on progradation-retrogradation. Further work will focus on the influence of NTG ratios and amalgamation on connectivity, as well as the reproduction of real-world systems. Studying the implications of the bathymetry on geometries and stacking patterns are another deliverable.

References

Prelat, A., Covault, J.A., Hodgson, D.M., Fildani, A., Flint, S.S. (2010). Intrinsic controls on the range of volumes, morphologies, and dimensions of submarine lobes. Sedimentary Geology, 232, 66-76.

Pyrcz, J.M., Catuneanu, O., Deutsch, C.V. (2005a). Stochastic surface-based modelling of turbidite lobes. AAPG Bulletin, v. 89, no. 2, 177-191.

Pyrcz, J.M., Sech, R.P., Covault, J.A., Willis, B.J., Sylvester, Z., Sun, T. (2005b). Stratigraphic rule-based reservoir modelling. Bulletin of Canadian Petroleum Geology, 53 (4), 287-303.

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