

Hierarchical characterisation of submarine channels for compression based object modelling

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1. Introduction

Submarine channels deposits can host large hydrocarbon accumulations but are challenging from a reservoir modelling perspective. In confined systems, a hierarchical classification scheme suitable for object based modelling of these systems is shown conceptually in Fig 1.1.

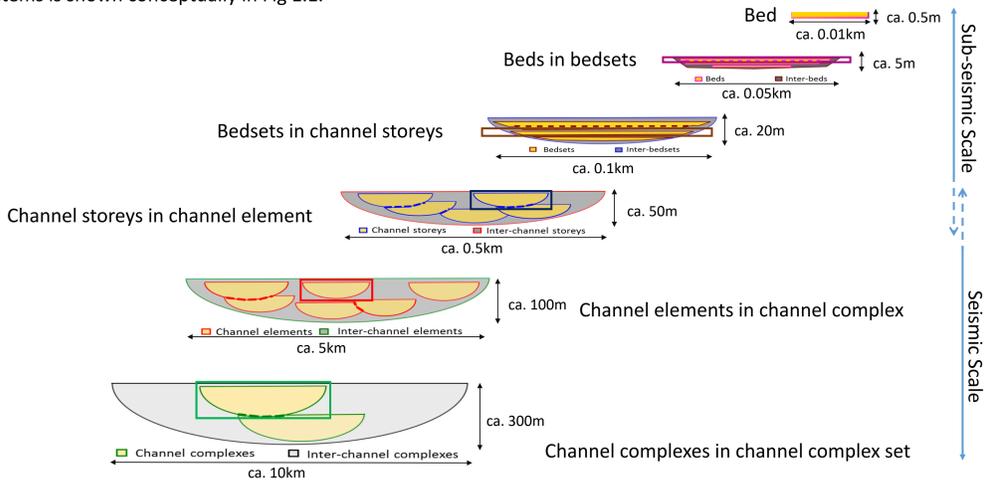
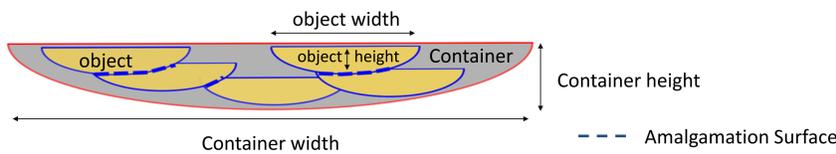


Figure 1.1. Conceptual model of hierarchical submarine channel fills, nomenclature adapted from Sprague et al. 2005.

At each hierarchical level, this classification scheme (Fig. 1.1) can be used for measuring stacking and dimensional data as shown in Fig. 1.2. This data is used as input in the modelling workflow as described in sections 2-4.



Dimensional data:-

- Fractional Thickness: Object height / Container height
- Fractional Width: Object width / Container width

Stacking data:-

- Volume Fraction (VF): Fraction of container volume occupied by objects
- Amalgamation Ratio (AR): Sum of lengths of amalgamation surfaces as a proportion of sum of lengths of all object bases

Figure 1.2. At each hierarchical level in Fig. 1.1, exists a container-object pair and AR and VF can be measured as shown.

2. Stacking and dimensional data measured from outcrop example

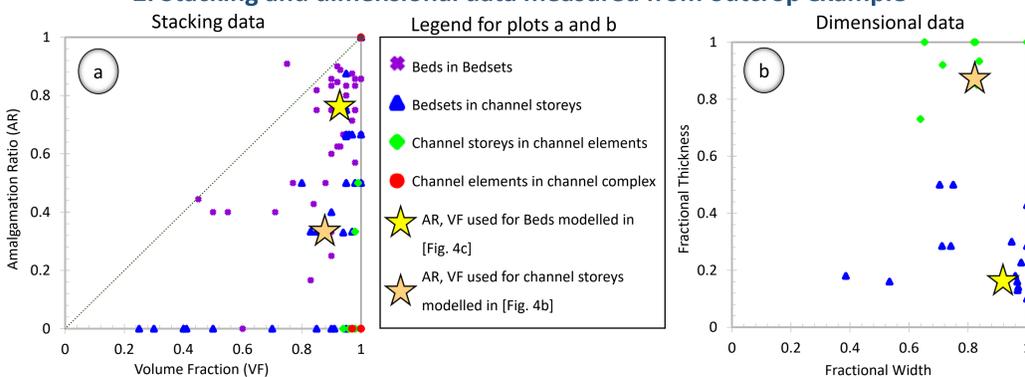


Figure 2. (a). Stacking data of four and (b). Dimensional data of two hierarchical levels of the Beacon Channel Complex.

The outcrop is a slope channel complex exposed in the Brushy Canyon Formation, U.S.A. Previous studies focussed on the architecture of the channel complex (e.g. Pyles et al. 2010) have characterized the system in a hierarchical framework. Using the scheme shown in Fig. 1.1, we have reinterpreted the system (e.g. Soni et al. 2016) for our measurements (e.g. Fig. 1.2). Overall, VF is greater than AR for all hierarchical levels. A systematic trend of higher AR at smaller hierarchical levels is seen in Fig. 2a. In other words, beds are more amalgamated in bedsets than bedsets in channel storeys and so on. This suggests that the nature of erosion at small scales (bed scale) is higher than large scales (channel scale). Similar fractional widths of bedsets and channel storeys (Fig. 2b, x-axis) in their respective containers indicates inheritance of container widths by objects contained in it. Distinct fractional thicknesses (Fig. 2b, y-axis) for the two levels indicates the abundance of bedsets in channel storeys than channel storeys in channel element.

3. Necessity of compression method

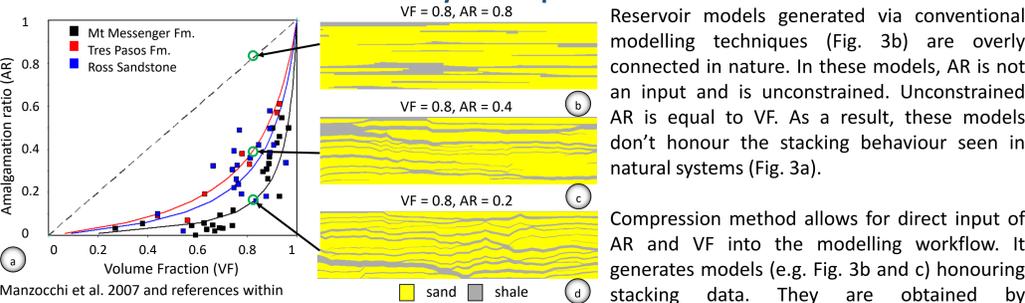


Figure 3. (a). Stacking data for three deep-water deposits. (b-d). 2D models for VF=0.8 but different AR. (e) are outputs of compression modelling whereas (b) is from conventional modelling.

6. Conclusions and the future work

The geomodelling workflow discussed above generates realistic reservoir scale but bed-resolution 3D models. Sub-seismic scale heterogeneities in the model are constrained by using channel shaped objects at different hierarchical levels. Objects at these levels stack in the way we see them in the outcrop honouring the stacking data at each level (sections 1 and 2). Understanding the role of hierarchical heterogeneities on fluid movement in the reservoir is a key area of research and concern while developing it. Realistic models generated using this workflow and flow simulated for some examples (sections 3, 4 and 5), will be carried out extensively to answer specific questions regarding sweep, drainage, impact of shale drapes, sandbody compartmentalization and well placement.

4. Compression based object modelling of channel complex

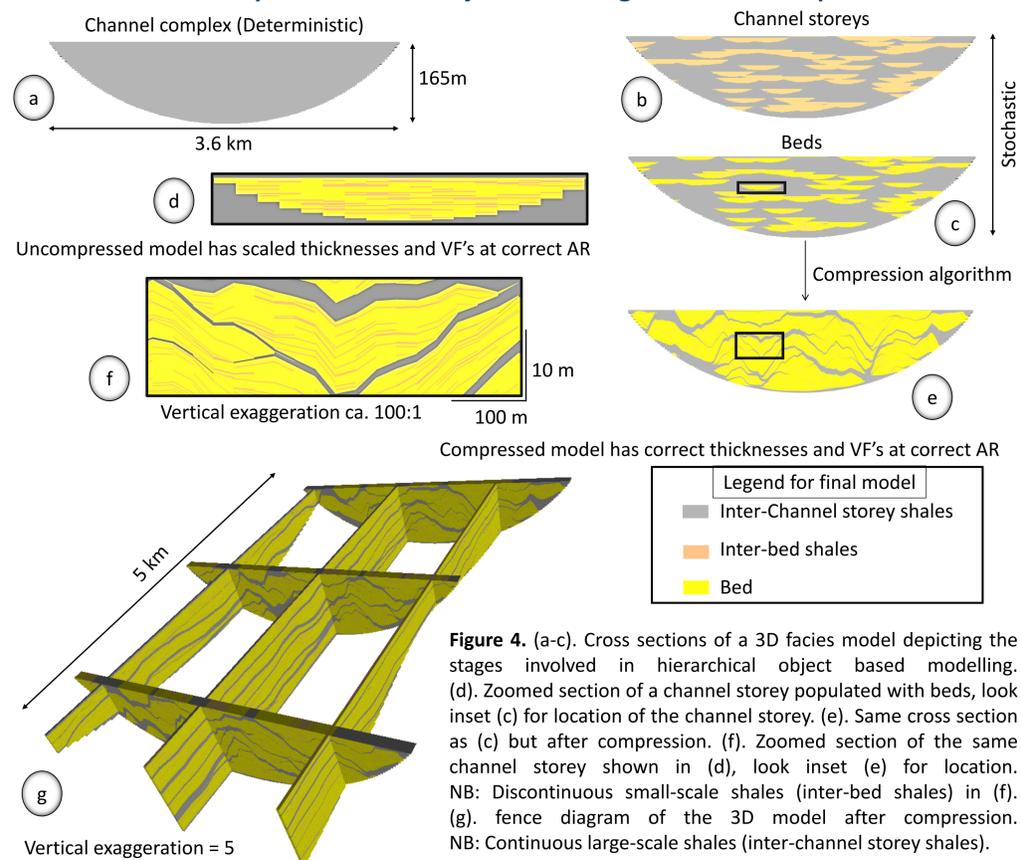


Figure 4. (a-c). Cross sections of a 3D facies model depicting the stages involved in hierarchical object based modelling. (d). Zoomed section of a channel storey populated with beds, look inset (c) for location of the channel storey. (e). Same cross section as (c) but after compression. (f). Zoomed section of the same channel storey shown in (d), look inset (e) for location. NB: Discontinuous small-scale shales (inter-bed shales) in (f). (g). fence diagram of the 3D model after compression. NB: Continuous large-scale shales (inter-channel storey shales).

Hierarchical object based modelling is carried out starting with a deterministic channel complex (Fig. 4a) and stochastically populating it with two smaller hierarchical levels i.e. channel storeys and beds respectively (Fig. 4b and c). The target AR and VF values used at these levels is represented by stars in Fig. 2a. Similarly, the target/correct fractional thicknesses used for them (prior scaling) are shown in Fig. 2b. The facies model (Fig. 4c) is generated using scaled volume fractions (i.e. = target AR values) and thicknesses. This scaled (or thinner) model is then used as input to the compression algorithm. Using the target AR and VF values for determining the amounts of expansion (>1) and compression (<1), the compression algorithm targets grid cells occupied by sand and shales at different hierarchical levels. The resultant model (Fig. 4e & g) honours stacking and dimensional data (Fig. 2) and is therefore more realistic.

5. Flow simulation of realistic reservoir model

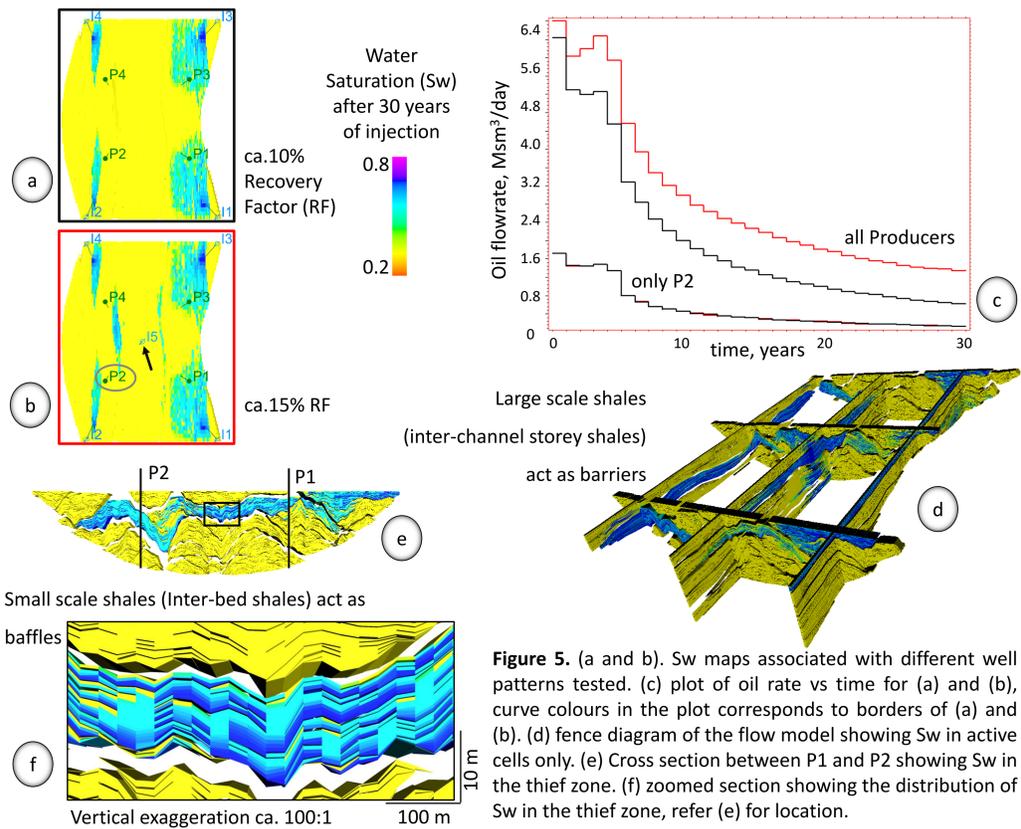


Figure 5. (a and b). Sw maps associated with different well patterns tested. (c) plot of oil rate vs time for (a) and (b), curve colours in the plot corresponds to borders of (a) and (b). (d) fence diagram of the flow model showing Sw in active cells only. (e) Cross section between P1 and P2 showing Sw in the thief zone. (f) zoomed section showing the distribution of Sw in the thief zone, refer (e) for location.

The realistic reservoir model (Fig. 4g) is assigned constant petrophysical properties. Non-net shales are impermeable, permeability in the net sandstone (i.e. all bed objects) is isotropic ($k = 100$ md). Porosity and initial Sw of the sandstone is 0.2. Constant value of these properties enable deterministic investigation of heterogeneities on flow of in-situ oil and injected water.

The reservoir model was simulated with a realistic production scenario. Water injection and drainage was carried out using 5 Injectors and 4 Producers (Fig. 5b). The well-pattern was chosen based on additional oil recovered after adding an injector (I5) to an earlier case (Fig. 5a). Although a barrier separates the drainage volume associated with P2 and irrigation volume associated with I5 *sensu* no additional oil production in P2 (Fig. 5c), its location is justified given its contribution to other producers.

Continuous large scale shale barriers prevent a homogeneous Sw at reservoir scale. Compartments of highly and poorly swept sandbodies are encountered (Fig. 5d) which lead to early water breakthrough (i.e. 5 years of flooding). No additional thief zones are encountered since the first water production in the remaining years of injection (Fig. 5e). Highly eroded discontinuous shale baffles (small scale) prevent homogeneous Sw at compartment scale (Fig. 5f).

7. References:-

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