Supplementary Material to 'Estimation of detachment depths and displacements from the area-depth markers of contractional growth structures; testing the 'inverse line' concept'

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The supplementary material to this article consists of two items:

1. Supplementary Methods, in which the procedure for time-to-depth conversion and its uncertainties is explained in more detail, with one associated Supplementary Figure.
2. Supplementary Table. A table with four tabs in which following is reported:
    a. Tabs A and B report the output parameters for all the models presented in the paper
    b. Tabs B and C report the intersections referred to in Figure 18A and B, and 18C and D, respectively.

Supplementary Methods: time-to-depth conversion

The Niger Delta and Ionian Basin time seismic lines were time-to-depth converted using a single-layer velocity model. An initial velocity (V_0) at the sediment-water interface of 1700 m/s was assumed as an average value appropriate for saturated shale and sand sections, together with a moderate velocity gradient (k) of 0.5

(Mavko et al., 2009). Then, time-to-depth conversion is achieved by applying (Slotnick and Geyer, 1959):

$$Z = \frac{V_0 e^{kt-1}}{k}$$

where Z is layer thickness in m, and t is the one-way travel time for layer thickness in seconds (Supplementary Figure 1).

In the case of the Niger Delta sections, this results in seismic profiles which bottom is at 4.25-4.5 km depth below the sediment surface. This is consistent with time-to-depth conversions as seen, for example, in Totake et al. (2017). However, it must be noted that in their tests they found the results of the single-layer depth conversion unsatisfactory when compared with the results of a more detailed three-layer velocity model. This is because only in the latter the predictions of detachment depth matched the interpretated surface, and layer-parallel strain (LPS) was within reasonable values (<-7%). In the Niger Delta sections used in this work, the greatest mismatch between interpreted and ADS-predicted detachment surface is found in lines N29 and N34, where the area-depth graph predicts a deeper detachment than observed. The rest of the sections show, conversely, more accurate predictions with minimal discrepancies. However, this work investigates the relationships between the actual pregrowth best-fit and the inverse line, regardless of how well the pregrowth line predicts the detachment surface. Because the method for time-to-depth conversion has been kept consistent in all cases, the ADS results and the calculations regarding the inverse line should at least be comparable between sections, and remain valid.

In the case of the Ionian Basin sections, no time-to-depth converted seismic with which to calibrate the results obtained here is available. Butler et al. (2014) suggested that the upper evaporite layer, which is 200 ms TWT thick, may be equivalent to a 400-500 m thick package. The depth conversion performed here yields a thickness of 350 m for this layer, which is slightly below their estimate, but still in the same order of magnitude.

Therefore, if more accurate velocity models were used it is possible that the relationships between the pregrowth and inverse line could be affected, because these depend on the obtained depths for both the growth and pregrowth markers. Consequently, the results presented in this work must be considered as a first approximation to the viability of the inverse line, which should be further tested in seismic sections with better control on their time-to-depth conversion.

Supplementary Figure captions

Supplementary Figure 1. Example of the time-to-depth conversion performed on the seismic lines with the N18 section from the Niger Delta dataset as an example. A single-layer velocity model with increasing velocity from the sediment surface to the bottom of the section was used in all cases. Left, time and time-to-depth converted sections. Right, layer thickness (Z) as a function of two-way-travel time (s) for the parameters used in time-to-depth conversion.

Supplementary Table captions

Supplementary Table 1. A) All parameters calculated for models in model sets A and B; displacement rate (D, m/step), uplift rate (U, m/Step), sediment-to-uplift ratio

(S/U), detachment depth calculated from the inverse line (h_{d2}), displacement calculated from the inverse line (D2), difference between detachment calculated by the inverse and pregrowth line (h_{d2}-h_{d1}), and displacement ratio between actual displacement and that from the inverse line (D1/D2). B) All parameters calculated for models in model sets C and D; displacement rate (D, m/step), uplift rate (U, m/Step), sediment-to-uplift ratio (S/U), detachment depth calculated from the inverse line (h_{d2}), displacement calculated from the inverse line (D2), difference between detachment calculated by the inverse and pregrowth line (h_{d2}-h_{d1}), and displacement ratio between actual displacement and that from the inverse line (D1/D2). C). Properties (S/U, D1, D2) of the intersection points referenced in Figures 18A and B. D). Properties (S/U, D1, D2, and their ratio) of the intersection points referenced in Figure 18C and D.

Supplementary References

Butler, R. W. H., R. Maniscalco, G. Sturiale, and M. Grasso, 2014, Stratigraphic variations control deformation patterns in evaporite basins: Messinian examples, onshore and offshore Sicily (Italy): Journal of the Geological Society, v. 172, no. 1, p. 113–124, doi:10.1144/jgs2014-024.

Mavko, G., T. Mukerji, and J. Dvorkin, 2009, The Rock Physics Handbook: Tools for Seismic Analysis of Porous Media: Cambridge University Press, doi:10.1017/CBO9780511626753.

Slotnick, M. M., and R. A. Geyer, 1959, Lessons in Seismic Computing: Society of Exploration Geophysicists, doi:10.1190/1.9781560802563.

Totake, Y., R. W. H. Butler, and C. E. Bond, 2017, Structural validation as an input into seismic depth conversion to decrease assigned structural uncertainty: Journal of Structural Geology, v. 95, p. 32–47, doi:10.1016/j.jsg.2016.12.007.