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Supplemental Material

Supplemental File S1. Additional methodology, and figures

Supplemental File S2. All data and statistics

Supplementary file 1

"A multivariate examination of the sediment-deficient southeast Australian continental shelf"

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METHODS FOR SELECTING THE SHELF BREAK ALONG A SHELF-SLOPE PROFILE

The shelf break is the position where the shelf meets the slope. This point is marked by a change in the shelf gradient and a transition from sediment facies influenced by wave and tidal energy to those influenced by gravity-driven processes. The shelf break occurs where there is a significant change in the gradient along a shelf to slope profile. However, significance is not quantifiable, and there is no report in the scientific literature on how significant the change in gradient should be. Thus, to remove subjective biases, alternative definitions to determine the position of the shelf break have been proposed.

O'Grady et al. (2002) proposed that the shelf break is located where the highest curvature value occurs along a shelf profile. This proposal is supported by curvature maps produced by O'Grady et al. (2002) from the southern Greenland margin (Fig. S1A). However, curvature maps from southeast Australia have very different results (Fig. S1B). We find the zone of higher curvature values to be inconsistent in SE Australia, not continuous. Furthermore, the zone is often located in much deeper water than where most researchers would interpret the shelf break to occur (sometimes >4000 m; Fig. S02).

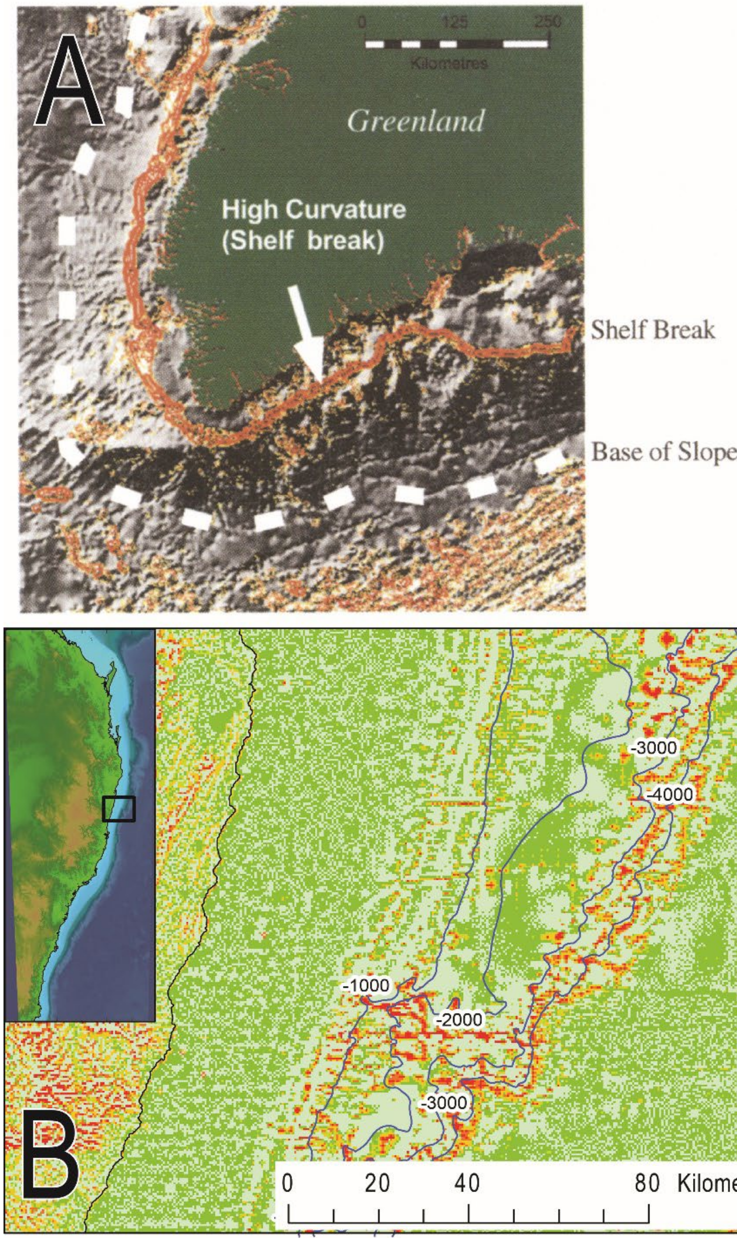

Fig. S1. A) Figure from O'Grady et al. (2002) showing how the maximum curvature zone in the artic correlates with the position of the shelf break. B) Result from the same analysis in part of SE Australia showing how the maximum curvature zone is not a good indication of the shelf-break. Red values = high curvature, orange = medium curvature, green = low curvature, grey = no, or positive curvature.

Curvature can also be calculated along a shelf profile (Fig. S2). Figure S2 and S3 show that using the degree of curvature to find the position of the shelf break in SE Australia produces poor results. This result might occur for some shelf profiles because they are not entirely perpendicular to the shelf and cut across slope canyons. However, as shown in figure S1, identifying the maximum curvature point for a given shelf profile will not produce reliable results. Computing the curvature of the shelf profile in Matlab was achieved by using the curvature function (Mjaavatten, 2022).

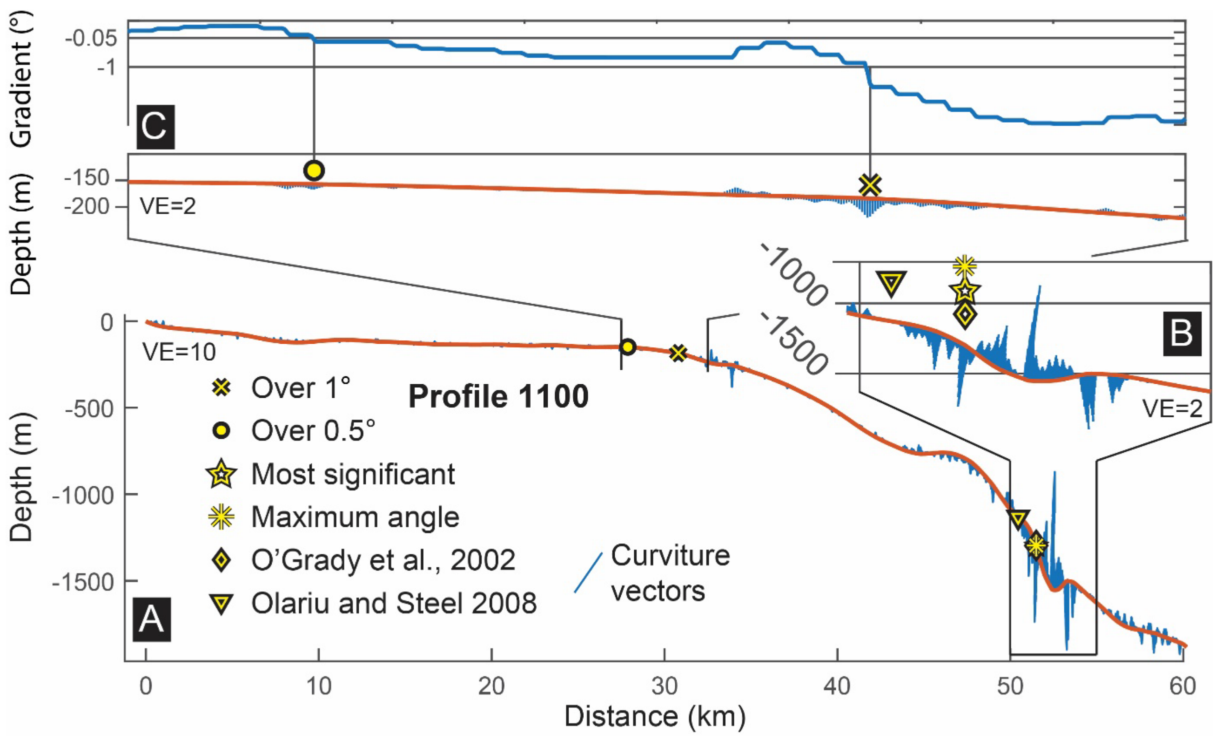

Fig. S2. A) Shelf profile #1100. See Fig. S2F for the location of this profile. B and C) Two zoomed-in images with less vertical exaggeration (x10 vs x2). This figure highlights the problems associated with using the maximum curvature of a profile to identify the shelf break. See Fig. S2 for other examples where the maximum curvature of the shelf profile occurs in water depths >1000 m. Over 1°: method developed here and used in for the study. Over 0.5°: finds the point where the average slope of the shelf profile increases beyond 0.5°.

To find the most significant change in a slope along a shelf profile, Olariu and Steel (2009) developed a method that identified the maximum ratio between the gradients of the shoreline and a designated point moving basinward and that point to another point 30 km basinward. Unfortunately, as shown in figures S2 and S3, this method also produces results that suggest the shelf break occurs in deeper water (>1000 m). To reduce this limitation, Olariu and Steel (2009) used constraints, such as the shelf break must occur within 30 km of the shoreline and between 50–300 m water depth. Applying these constraints would likely “fix” their method. However, given the desire to scale these procedures globally, constraints would either have to be adapted based on the particular margin or scrapped completely. In other words, the constraints significantly limit this approach. No constraints are applied in all the examples shown in the supplementary figures or those analysed in the manuscript.

In addition to the above-mentioned methods, we developed two approaches to identify the most significant change in a gradient along a shelf profile. The first finds the highest negative angle (i.e., the angle below the profile) of the shelf profile, and the second finds the most significant change in the gradient. However, both methods produced similar results to the previous attempts and were not considered helpful in identifying the shelf break. The results of these methods suggest that the most significant change in slope along a given shelf profile does not relate to the shelf break and tends to be much deeper (Fig. S3). Therefore, identifying the significance of the change of slope is not viable when developing a method to determine the shelf break along a given shelf-slope profile.

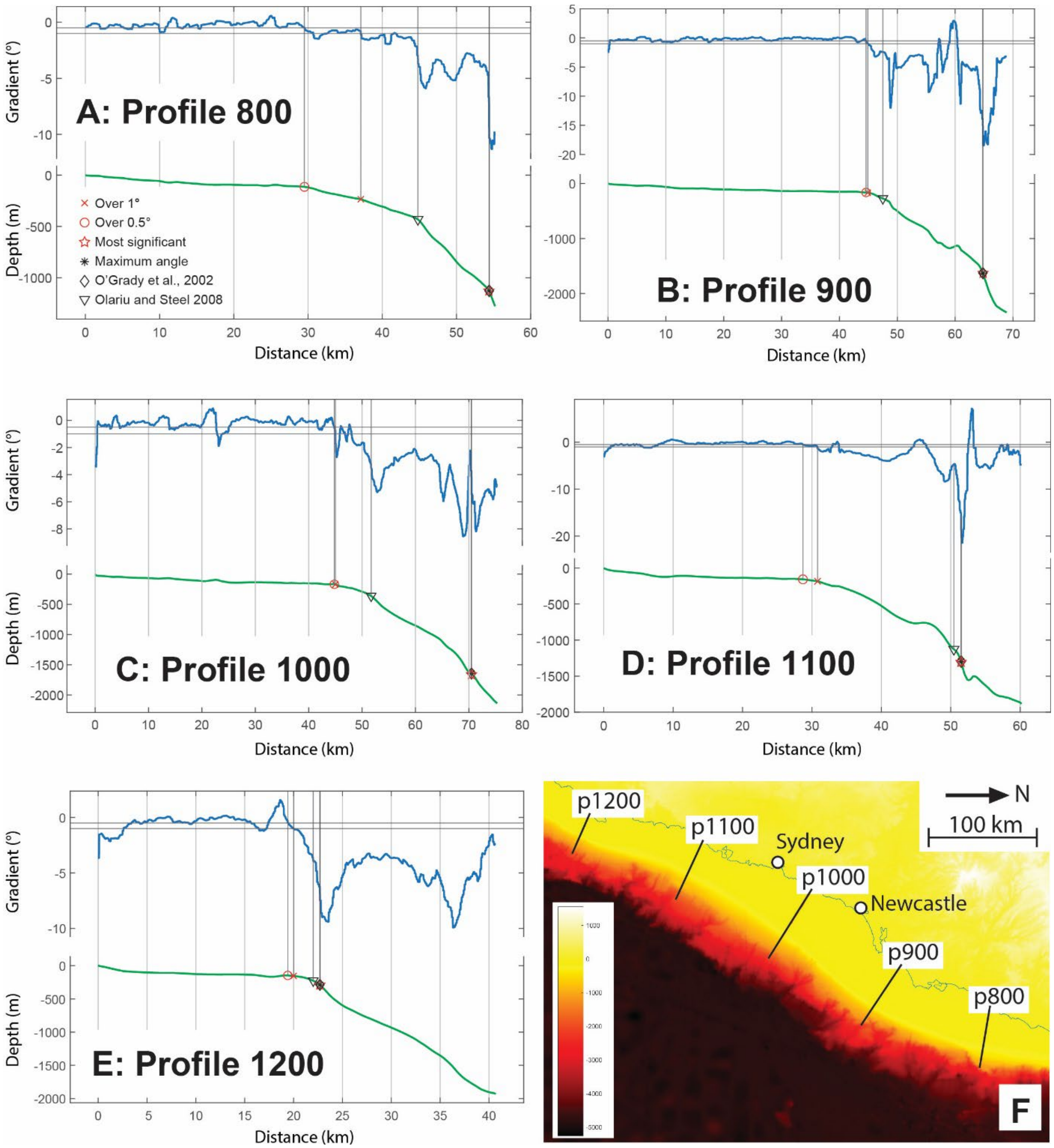

Fig. S3. Shelf profiles (green lines) from SE Australia with the results of the computed shelf-breaks. Vertical exaggeration is not fixed and dependent on the profile. Blue lines are the associated gradient profiles for each shelf profile. Horizontal lines mark -0.5° and -1°. The location of each profile is shown on the map (F) where the green line represents the coastline. p = profile.

An alternative approach to identifying the shelf break is to identify a point along the shelf-slope profile where the slope angle increases beyond a specific value and, on average, maintains that value. This method was achieved by calculating the slope of the profile at 100 m intervals. Following this, any interval that did not meet the condition (i.e., slope <1°) was removed, and the slope was calculated from the point before and after the deleted section. This procedure is done 100 times until the point closest to the shoreline marks the transition from an average slope of <1° to >1°. An alternative approach that produces similar results for many profiles is to use changepoint functions; however, this approach was not as successful.

Ultimately, selecting the method for calculating the position of the shelf break suffers a similar fate as deciding how significant the change in the slope should be—it is subjective. There are statistical tests that could aid in deciding which method is least subjective, or most accurate, but it requires a clear definition of where the shelf-break occurs, which, surprisingly, is not entirely obvious within the scientific literature. The computational approach used in this manuscript may not be the best or most accurate approach; however, it is consistent for all the profiles and adheres to previous findings suggesting that the slope gradient is typically >1°. However, we also experimented with varying modifications in the mean slope (from >0.05° to 2°) (Fig. S5). The decision to choose >1° or another value is subjective and may need consideration of the specific margin or setting. Further research is necessary to comprehend the variations in slope along the shelf-slope profile. For SE Australia, Boyd et al. (2004) selected the shelf break based on where the shelf profile became >0.6° (Fig. S4).

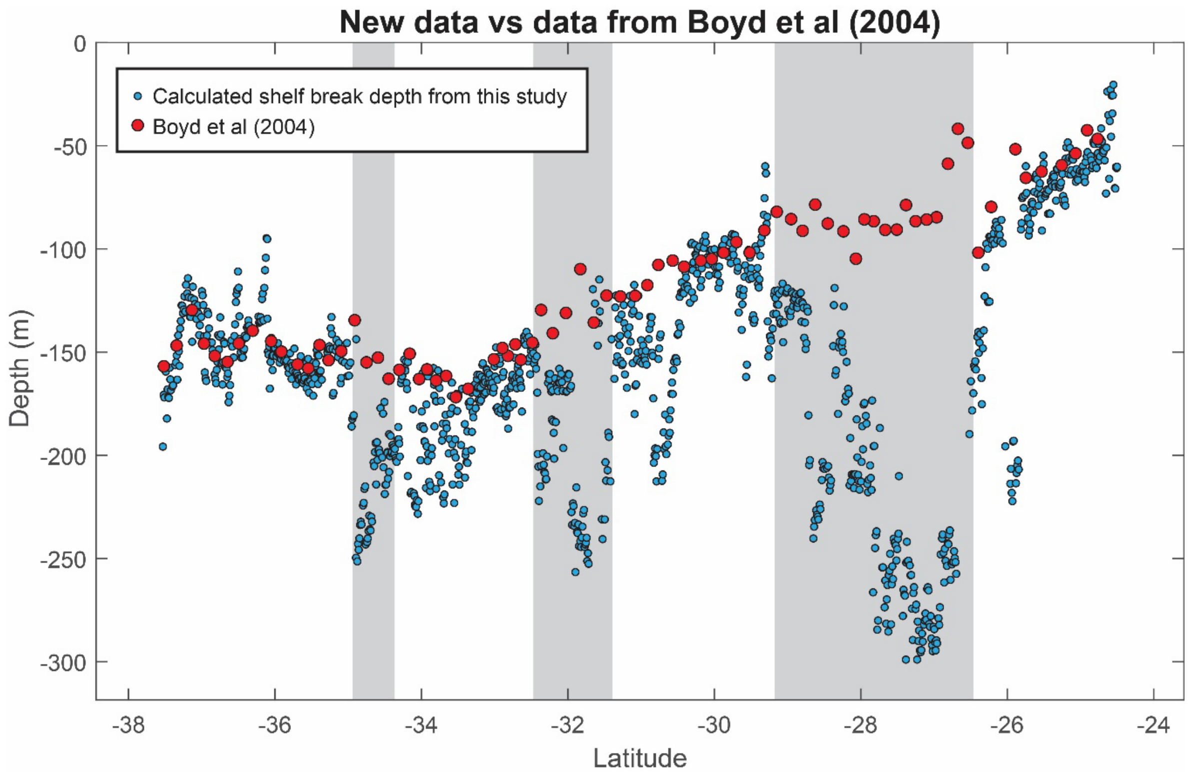

Fig. S4. Comparison of the calculated shelf break depth vs latitude against previous results (Boyd et al., 2004).

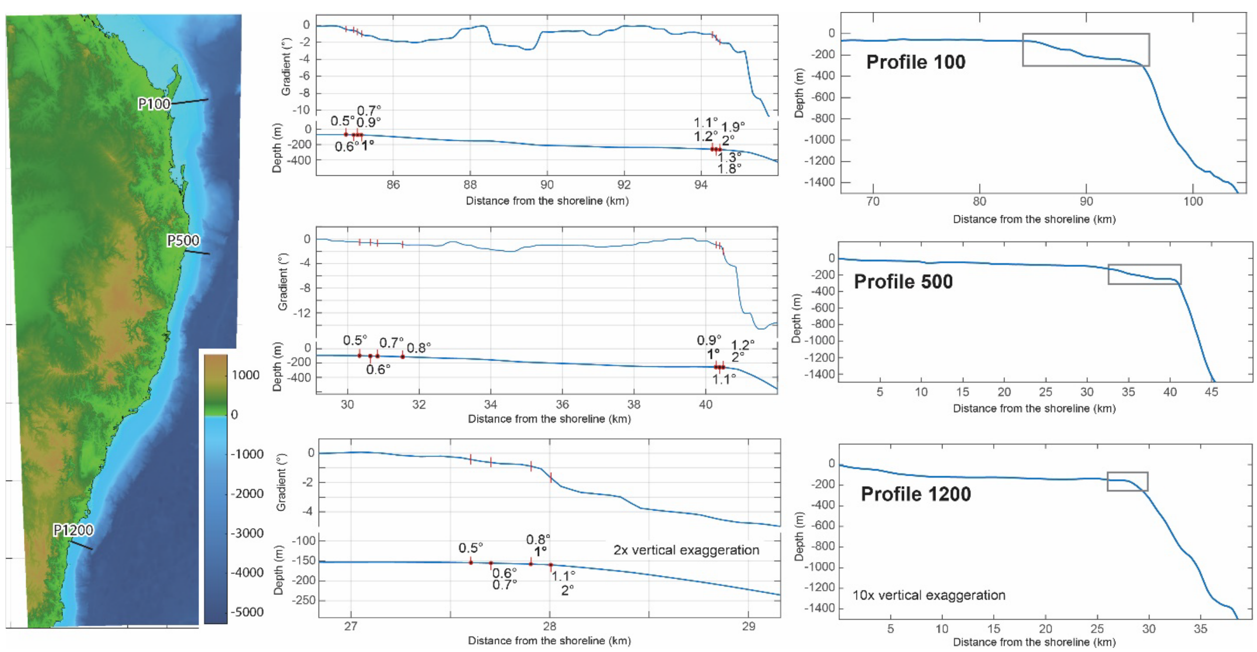

Fig. S5. Comparison of different degrees in the changes in the slope to determine the shelf break.

INFORMATION ON CLUSTERING AND DETERMINING SECTION BOUNDARIES.

Several clustering techniques were examined when analysing the individual shelf profiles. The clustering methods were used to identify shelf sections and boundaries where natural changes in shelf morphology occur along strike. Ten clusters were initially selected; however, ten do not account for all the variability. Therefore, the number of clusters was increased by one until the data separated appropriately. The results suggest that there are 20 distinct sections along the southeast Australian shelf. However, the breaks between the sections are not always breaks, but are sometimes transitional (Fig. S5). Therefore, change point functions were used to identify where the boundaries occur (Fig. S7). Previous studies that utilised multivariate analysis used arbitrary boundaries.

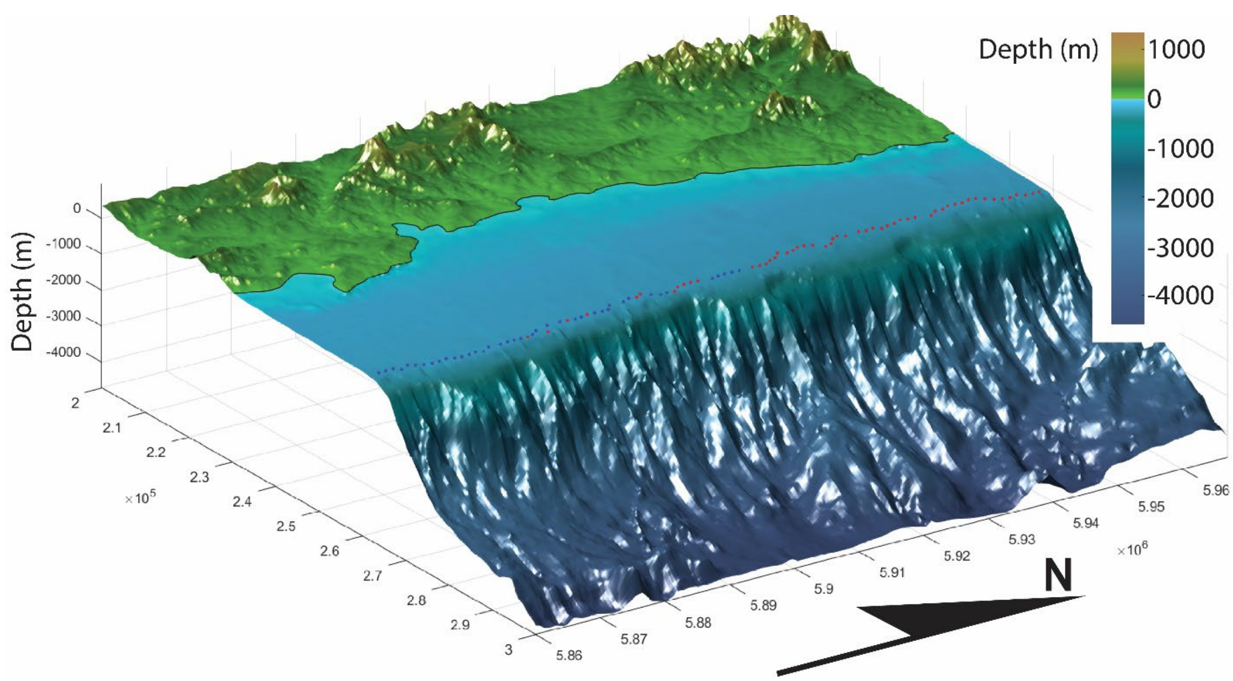

Fig. S6. Example of clustering results not finding breaks between the sections in southern NSW. Each dot represents a calculated shelf break position. The blue dots are ultimately section 1, and the red dots are section 2. These “transitional” boundaries between shelf sections occur at 7 locations in the southeast Australian dataset.

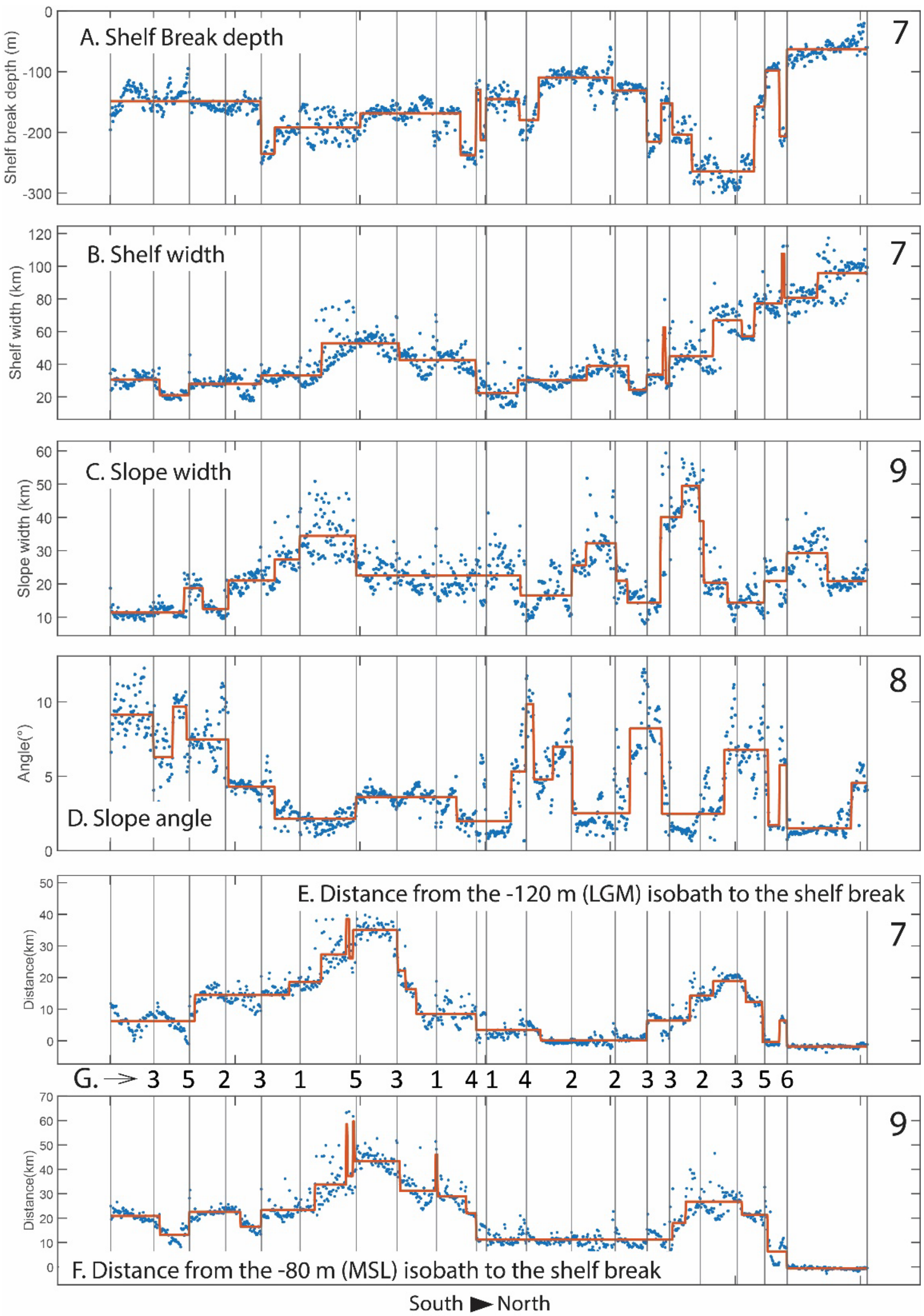

Fig. S7. Results of the changepoint function across all attributes of the entire dataset. Note that G represents the number of attributes that vary at the associated boundary. The numbers on the right of each plot show how many variations of that attribute shift at the group boundaries (i.e., how important was that attribute in defining group boundaries).

ADDITIONAL FIGURES

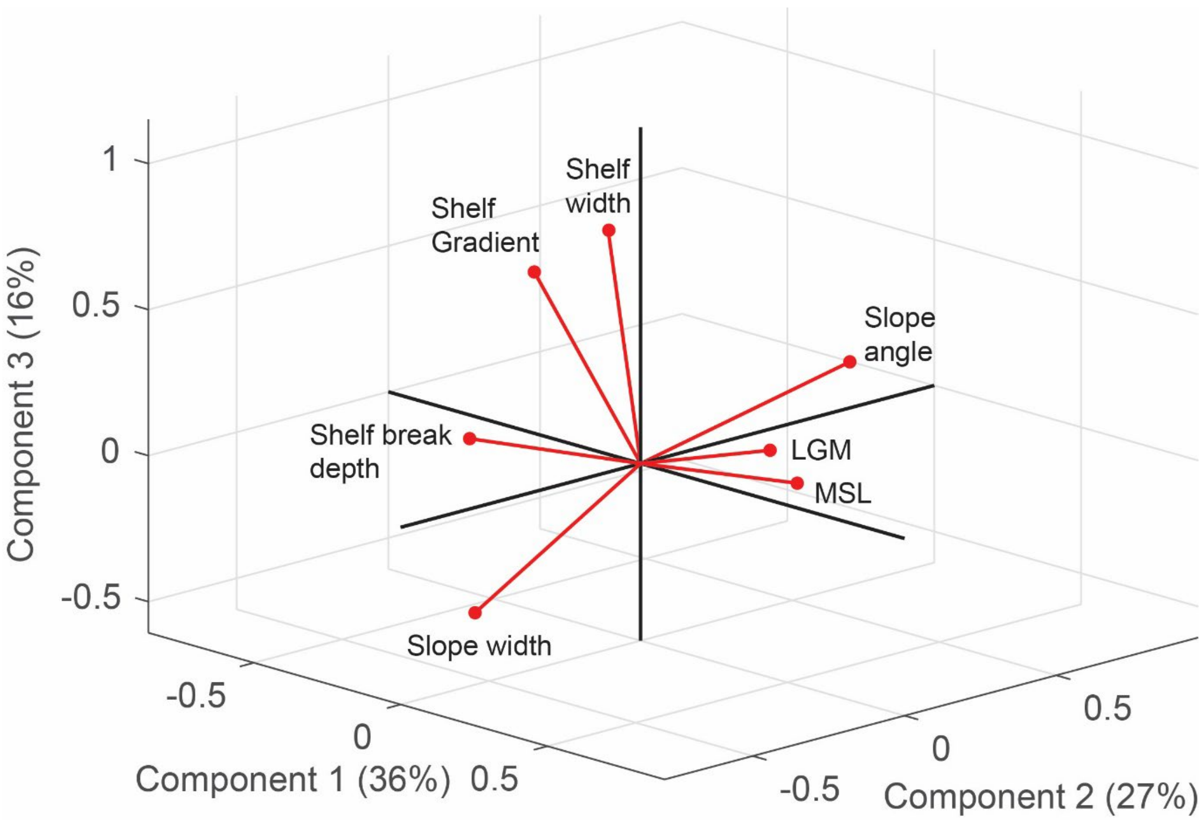

Fig. S8. The PCA analysis using the five main variables plus the lowstand shelf widths. MSL: Mean lowstand sea-level shelf width. LGM: Last glacial maximum shelf width.

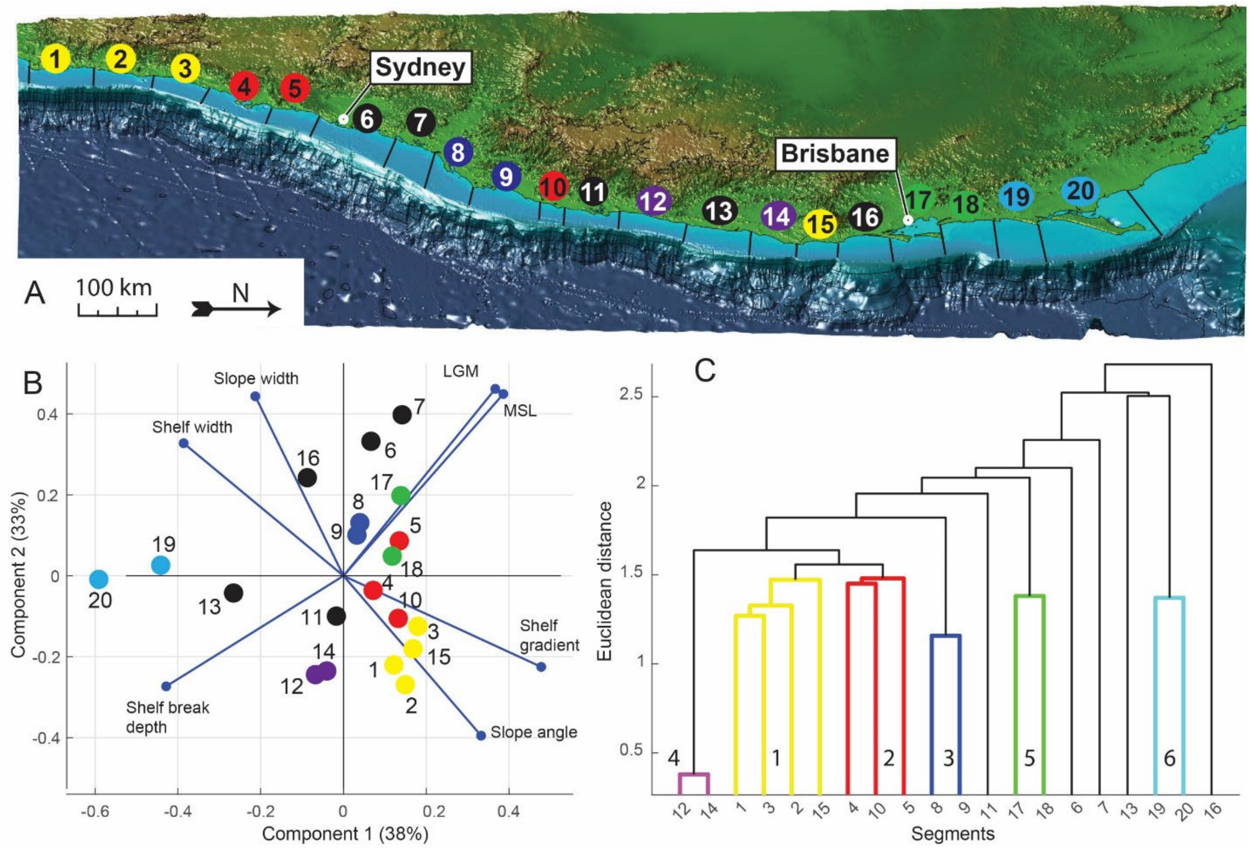

Fig. S9. (A) Map of the southeast Australian margin illustrating the section locations and their groups. (B) The principal component plot, colours, represents the grouping. Blue lines are the eigenvectors. (C) The dendrogram illustrates the degree of similarity between the sections.

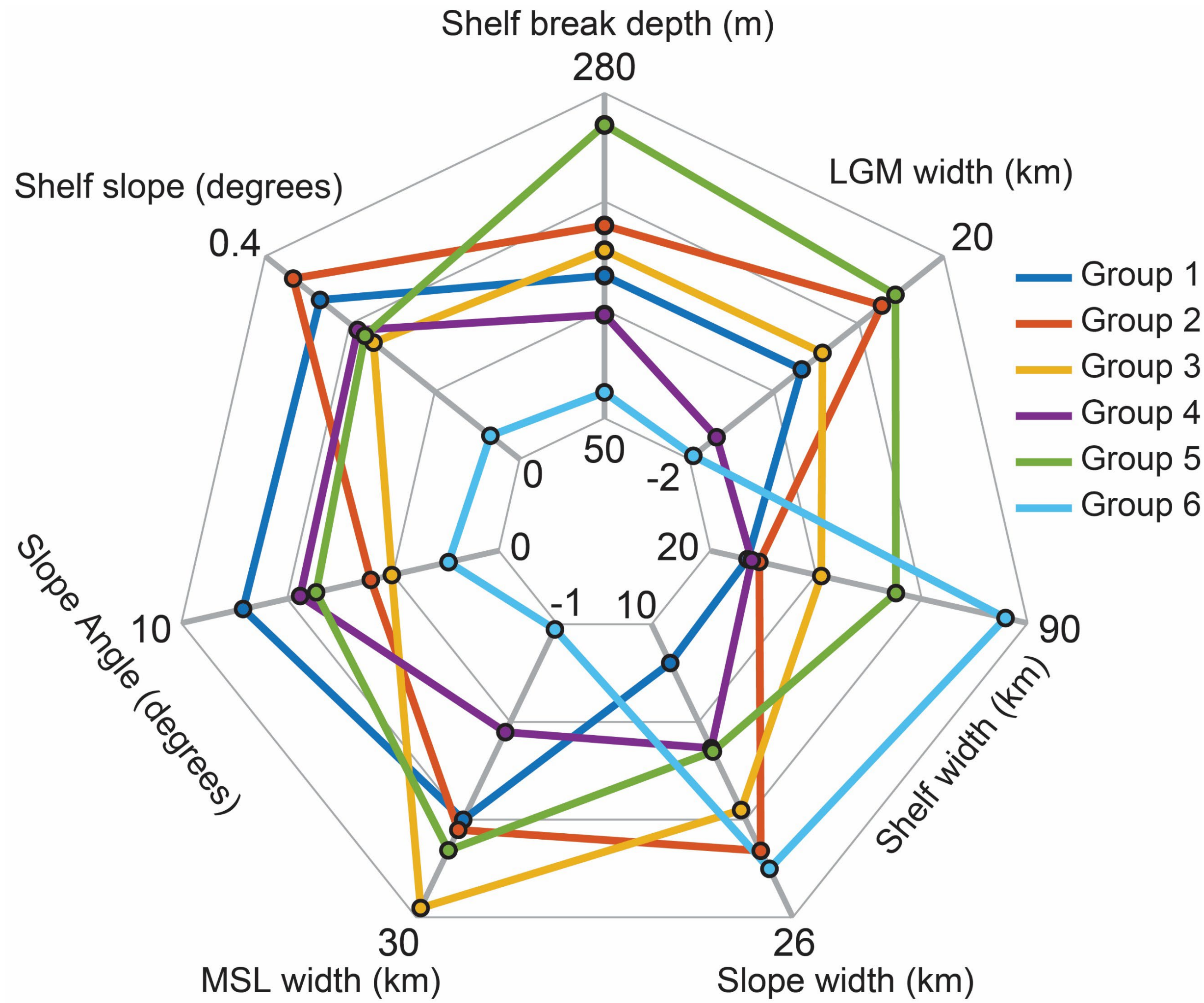

Fig. S10. Spider plot illustrates the relationships between the groups. The variables here are the same for the spider plots in the mean profile figures (Fig 12, 14:20).

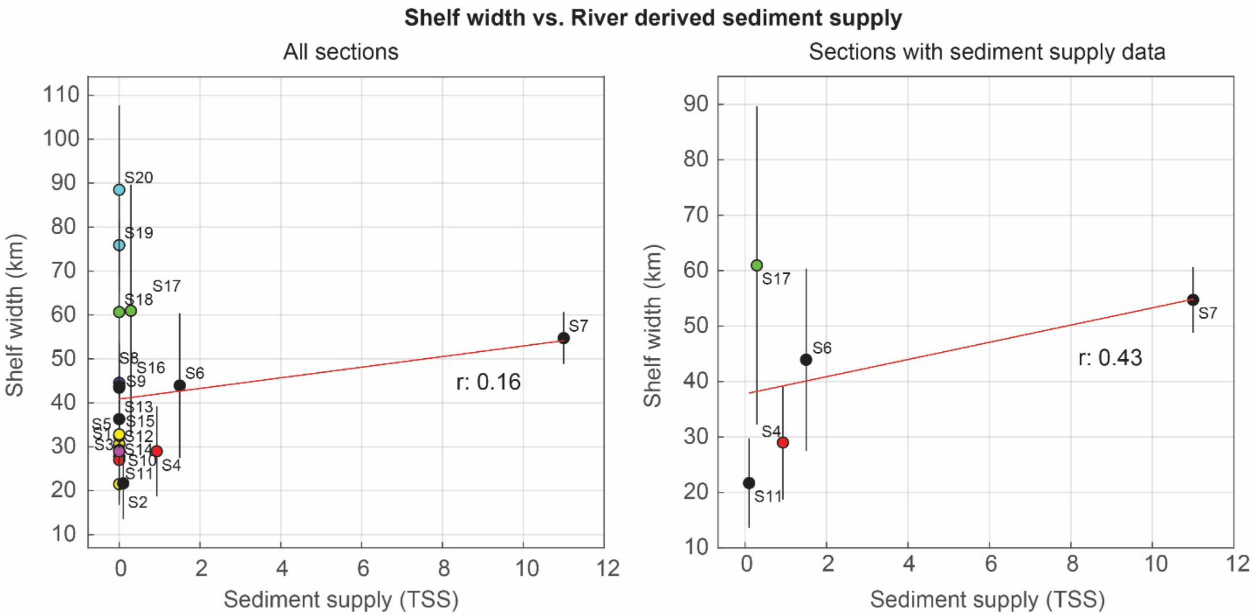

Fig. S11. Sediment supply against shelf width shows no to poor relationship.

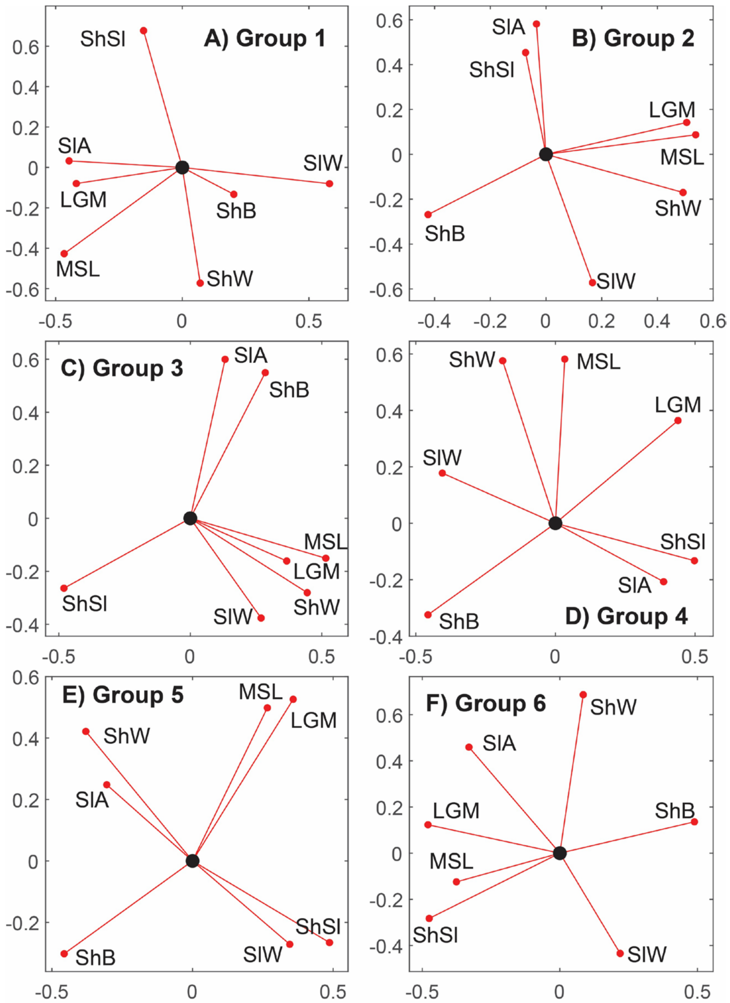

Fig. S12. Principal component eigenvectors for each group. Codes: ShB: Shelf Break, ShSl: Shelf slope, ShW: Shelf width, SlW: Slope width, SlA: Slope angle, MSL: Mean lowstand sea-level shelf width, LGM: Last glacial maximum shelf width.

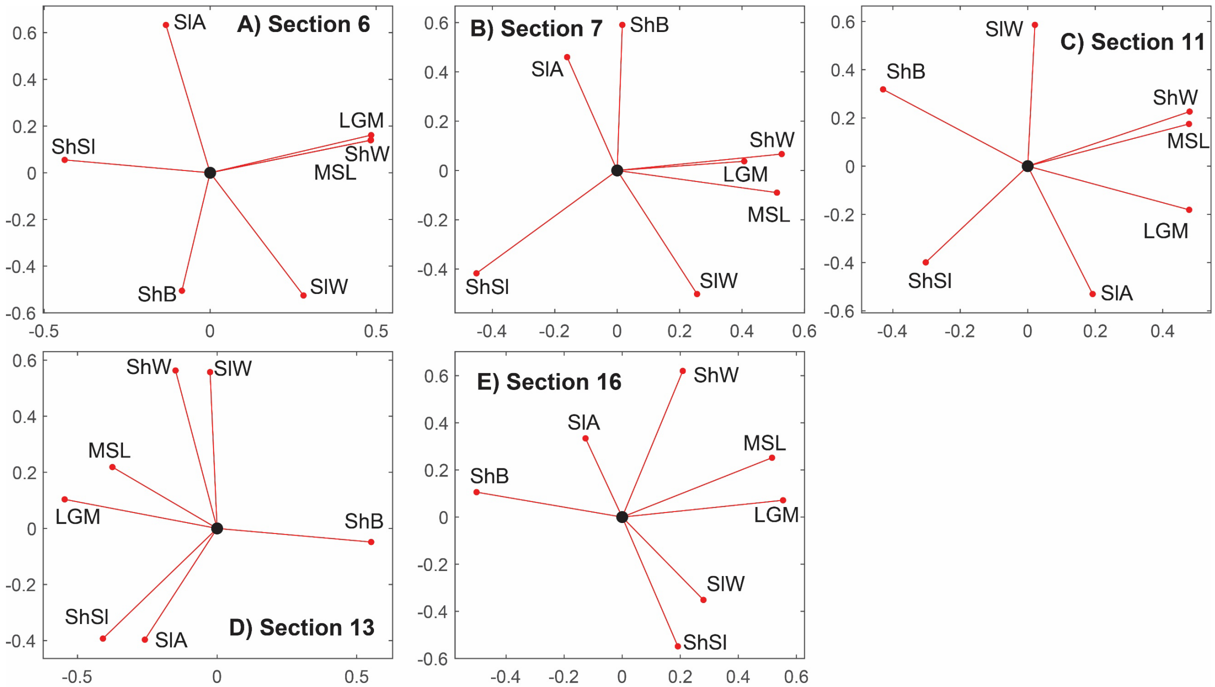

Fig. S13. Principal component eigenvectors for the outlier sections. Codes: ShB: Shelf Break, ShSl: Shelf slope, ShW: Shelf width, SlW: Slope width, SlA: Slope angle, MSL: Mean lowstand sea-level shelf width, LGM: Last glacial maximum shelf width.

REFERENCES

Boyd, R., Ruming, K., and Roberts, J., 2004, Geomorphology and surficial sediments of the southeast Australian continental margin: Australian Journal of Earth Sciences, v. 51, no. 5, p. 743-764.

O’Grady, D. B., Syvitski, J. P. M., Dowdeswell, J. A., and Cofaigh, C. Ó., 2002, Large-scale morphology of Arctic continental slopes: the influence of sediment delivery on slope form, Glacier-Influenced Sedimentation on High-Latitude Continental Margins, Volume 203, Geological Society of London, p. 0.

Mjaavatten, A (2022). Curvature of a 1D curve in a 2D or 3D space (https://www.mathworks.com/matlabcentral/fileexchange/69452-curvature-of-a-1d-curve-in-a-2d-or-3d-space), MATLAB Central File Exchange.

Olariu, C., and Steel, R. J., 2009, Influence of point-source sediment-supply on modern shelf-slope morphology: Implications for interpretation of ancient shelf margins: Basin Research, v. 21, no. 5, p. 484-501.