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Why do shelf-incising submarine canyons form? - Insights from global topographic analyses and regression trees

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The efficiency of environmental signal propagation from terrestrial sources to marine sinks highly depends on the connectivity of the sediment-routing system. Submarine canyons that couple river outlets with marine depocenters are particularly crucial links in the routing network as they convey terrestrial sediment, associated pollutants and organic carbon to the deep ocean. However, why and where submarine canyons incise into shelves is still poorly understood. Several factors were proposed, including narrow shelves along active continental margins, onshore sediment flux, more proximal sediment supply during sea-level lowstands, mass wasting along high-gradient continental slopes, and the occurrence of durable bedrock in adjacent catchments. In this study, we test whether we can predict shelf incision of submarine canyons from onshore and offshore parameters.

We used maps of global elevation and bathymetry and analyzed them together with a global compilation of 5900 submarine canyon heads. The analysis relies on bagged regression trees that predict the distance of each canyon head from the shelf edge as a function of numerous candidate predictor variables. These variables describe spatial relations of river mouths and canyons, shelf geometry, continental slope gradient, as well as numerous terrestrial catchment properties. Moreover, we added 120 m to the elevation of the present-day topography to simulate a coastal landscape during the Last Glacial Maximum (LGM) and recalculated the topographic terrestrial parameters and the shelf width.

The trained model explains 66% (R^2) of the variance within the data set with a root mean square error (RMSE) of 31 km and a mean absolute error (MAE, less sensitive to outliers) of 17 km. The highest predictor importance is consistently reported for the weighted distance from canyon heads to the adjacent river mouths during the LGM and the present-day catchment gradient. We find no significant influence of shelf width, continental slope gradient and sediment load, and the moderate fit of the model indicates that we are still missing one or more important controls on the spatial location of canyon heads. Our predictions may be refined by including a more detailed assessment of catchment lithologies, locations of submarine groundwater discharge, locations of tectonic faults, and longshore current directions. Notwithstanding, we conclude that our model identifies important controls on the spatial occurrence and shelf incision of submarine canyons

and sorts out much debated but seemingly unimportant variables.

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