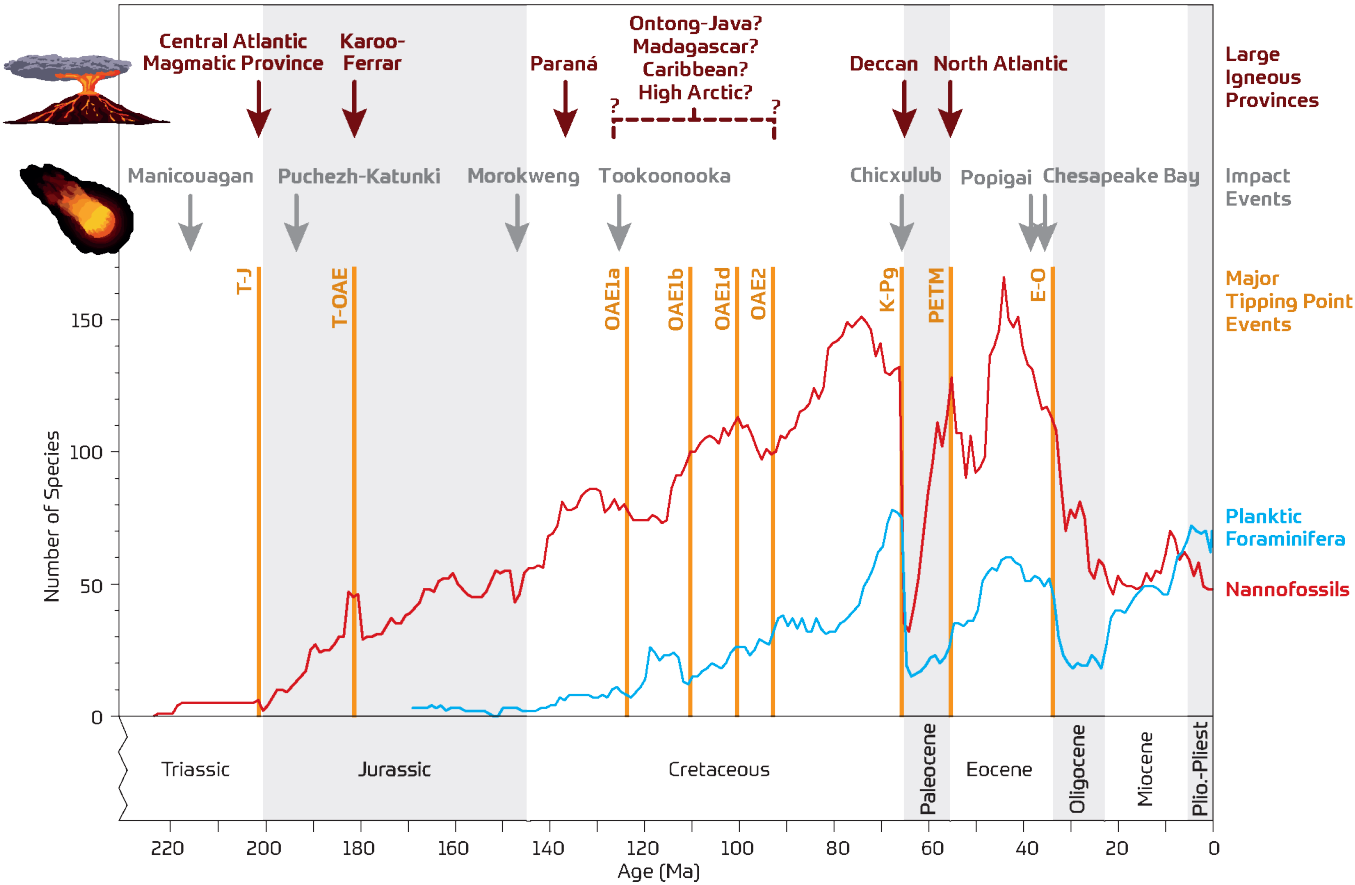

High-resolution scientific ocean drilling records of past Earth conditions and biodiversity allow us to identify the drivers of past tipping points in the Earth system, determine the consequences of exceeding tipping points, and investigate times when ecosystems were resilient to change. Species-level diversity of calcareous nannoplankton (red) and planktic foraminifera (blue) over the last 230 million years reveal extinction or radiation associated with major tipping points (orange lines). Over this interval there were seven impact events that produced craters >50 km in diameter (gray arrows), of which only Chicxulub is associated with a tipping point in the climate system and marine ecosystem. To better understand the role of large igneous provinces (brown arrows) in driving tipping point behavior, the timing and duration of these events (e.g., in the Cretaceous) and their environmental consequences need to be further constrained.

Note that the diversity data are presented in 1 million year bins, though it masks the complete extent of some extinction events, especially the K-Pg, in which 90% of both planktic foraminifera and calcareous nannoplankton species disappeared. T-J = Triassic-Jurassic boundary. T-OAE = Toarcian ocean anoxic event. OAE = Oceanic anoxic event. K-Pg = Cretaceous-Paleogene boundary. PETM = Paleocene-Eocene Thermal Maximum. E-O = Eocene-Oligocene boundary. *Sources: Modified from Lowery et al. (2020), https://doi.org/10.1146/annurev-earth-081619-052818; Impact event ages after Schmieder and Kring (2020), https://doi.org/10.1089/ast.2019.2085; LIP event ages after Clapham and Renne (2019), https://doi.org/10.1146/annurev-earth-053018-060136.*