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First absolute ages for early Eocene warming events: Implications and suggestions for future IODP / ICDP projects

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Relatively recently we have entered a new era in the research of early Cenozoic paleoceanography with the new records available from ODP Legs 198, 199, 207 and 208. Especially the sites from Legs 198 (Shatsky Rise) and 208 (Walvis Ridge) are providing the first complete spliced records ("composite sections") for the early Paleogene from drilling multiple holes, and the first depth transects for the early Paleogene for both the Pacific and Atlantic Ocean. Here, we present a unique 4.3 million year long interval recovered from Walvis Ridge that spans the late Paleocene to early Eocene (magnetochrons C24r, C25n, and upper C25r) containing the Paleocene-Eocene Thermal Maximum (PETM) and recently identified new hyperthermal events (Elmo layer, 'X' event). We have developed a detailed chronology by mainly using combined XRF scanning records and color data. To define a complete time series for the investigated interval new composite sections have been constructed for various sites (1263 and 1267 from Walvis Ridge, and 1051 from Blake Nose). Extensive spectral analysis reveals that the early Paleogene sedimentary cycles are dominated by almost perfect precession cycles modulated by the short (100-kyr) and long (405-kyr) eccentricity

cycle. The combination of direct counting of precession cycles at several sites and comparison to the land-based Zumaia section provides revised estimates for the age and duration of magnetochrons C24r and C25n. Comparison of the amplitude modulation of the precession cycle in the geological data with current astronomical computations of eccentricity suggests that the Paleocene-Eocene Thermal Maximum (PETM) and the Elmo layer are related to 100-kyr eccentricity maxima, but do not show any association to the 405-kyr eccentricity maxima.

For the first time it is now possible to provide robust estimates for the absolute ages of not just the magnetochrons C24r and C25n, but even more for the early Eocene warming events PETM, Elmo layer, and 'X' event using the amplitude modulation of the precession cycle in combination with cycle counting. Based on our study we stress that the integration between land-based records and deep marine successions is urgently needed to provide complete records of Earth's climate history. In fact, the integration of suitable land-based and deep-marine cyclic sedimentary successions, as successfully accomplished already for the Neogene, seems inevitable for the construction of a new accurate and stable stratigraphic framework for the Paleogene, the ultimative prerequisite for any further accurate and high-resolution climate reconstruction.