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An astrochronology for the lower to middle Eocene of the Mentelle Basin (Australia) and its implications for the geologic time scale

Maximilian Vahlenkamp (1), David De Vleeschouwer (1), Sietske Batenburg (2), Kirsty M. Edgar (4), Emma Hanson (4), Mathieu Martinez (3), Heiko Pälike (1), Kenneth G. MacLeod (5), Yong-Xiang Li (6), Carl Richter (7), Kara Bogus (8), Richard W. Hobbs (9), Brian T. Huber (10), and the Expedition 369 Scientific Participants

(1) MaRUM - Center for Marine and Environmental Sciences, University of Bremen, Germany., (2) Department of Earth Sciences, University of Oxford, South Parks Road, Oxford OX1 3AN, United Kingdom., (3) Université de Rennes, CNRS, Géosciences Rennes, UMR 6118, 35000 Rennes, France., (4) School of Geography, Earth and Environmental Sciences, University of Birmingham, United Kingdom., (5) Department of Geological Sciences, University of Missouri, Columbia MO 65211, USA., (6) School of Earth Sciences and Engineering, Nanjing University, 163 Xianlin Avenue, Nanjing 210046, P.R. China., (7) School of Geosciences, University of Louisiana at Lafayette, 611 McKinley Street, Lafayette LA 70504, USA., (8) International Ocean Discovery Program, Texas A&M University, 1000 Discovery Drive, College Station TX 77845-9547, USA., (9) Department of Earth Sciences, University of Durham, Durham DH1 3LE, United Kingdom., (10) National Museum of Natural History, Smithsonian Institution, MRC: NHB 121, 10th and Constitution Avenue NW, Washington DC 20560, USA.

The geologic time scale for the Cenozoic Era significantly improved over the last decades by virtue of advances in radioisotopic dating and the integration of these dates with astrochronologic and cyclostratigraphic results. However, to date the middle Eocene, remains a weak link. This so-called “Eocene astronomical time scale gap” reflects a lack of suitable study sections with clear astronomically forced variations in carbonate content, primarily due to large parts of the Eocene ocean being starved of carbonate. During International Ocean Discovery Program (IODP) Expedition 369, a carbonate-rich sedimentary sequence of Eocene age was recovered at Site U1514 in the Mentelle Basin (southwest Australia). The sequence consists of nannofossil chalk and exhibits a rhythmic character in its clay content. Hence, IODP Site U1514 provides an excellent opportunity to extract an astronomical signal and to construct an Eocene astrochronology. Here, we use X-Ray fluorescence (XRF) core scanning at 3 cm resolution to quantify the clay content variability. The XRF-derived ratio between calcium and iron content (Ca/Fe) precisely tracks the lithologic variability and serves as the basis for the U1514 cyclostratigraphic framework. Our astrochronology reveals a 16 million-year-long (40-56 Ma) nearly continuous history of Eocene sedimentation with variations paced by astronomical climate forcing. We supplement the high-resolution XRF data with low-resolution bulk carbon and oxygen isotopes, recording the long-term cooling trend from the Paleocene-Eocene Thermal Maximum (PETM) to the Middle Eocene Climatic Optimum (MECO). The well-expressed lithological alternations between clay-rich and clay-poor intervals reflect the combined imprints of obliquity and eccentricity. Our early Eocene astrochronology confirms existing chronologies based on deep-sea sites and Italian land sections. For the middle Eocene, the exceptional match of the tuned record at U1514 with astronomical solutions allows us to confirm astrochronologies previously suggested for the equatorial and South Atlantic (Site 702, 1260 and 1263) and to provide an important step towards a fully astronomically calibrated Cenozoic geologic time scale.