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Astronomical tuning and carbon isotope stratigraphy of the Maastrichtian in Sopelana and Zumaia (Basque country, N-Spain)

S. J. Batenburg (1,2), A. S. Gale (2), F. J. Hilgen (3), S. K. Hüsing (4), J. Laskar (5), X. Orue-Etxebarria (6), M. Sprovieri (1,7), and S. Voigt (8)

(1) Istituto per l'Ambiente Marino Costiero (IAMC-CNR), Naples, Italy (sbatenburg@gmail.com), (2) School of Earth and Environmental Sciences, University of Portsmouth, Portsmouth, United Kingdom, (3) Department of Earth Sciences, Utrecht University, Utrecht, the Netherlands, (4) Paleomagnetic Laboratory Fort Hoofddijk, Utrecht University, Utrecht, the Netherlands, (5) ASD, IMCCE-CNRS UMR8028, Observatoire de Paris, Paris, France, (6) Departamento de Estratigrafía y Paleontología, Universidad del País Vasco (UPV/EHU), Bilbao, Spain, (7) Istituto per l'Ambiente Marino Costiero (IAMC-CNR), Capo Granitola, Italy, (8) Institute of Geosciences, Goethe-University Frankfurt am Main, Frankfurt, Germany

Astronomical tuning has led to significant refinement of the Geological Time Scale for the Cenozoic, however the Late Cretaceous time scale still has potential errors of $\sim$0.5 Myr. The Basque sections of Sopelana and Zumaia (N-Spain) provide a high-resolution sedimentary archive encompassing the Maastrichtian up to the Cretaceous/Paleogene boundary. Rhythmic limestone-marl alternations, deposited in a hemipelagic setting, reflect the influence of the periodicities of eccentricity modulated precession. Starting from a K/Pg boundary age of 66.0 Ma, consecutive 405-kyr minima are tuned to the new astronomical solution La2011. This orbital tuning, together with the expression of individual precessional cycles, allows for unprecedented refinement of the Geologic Time Scale for the Maastrichtian with errors <100 kyr. The cyclostratigraphic interpretation is thoroughly tested by time series analysis of magnetic susceptibility and colour reflectance data. A cyclostratigraphic framework and orbital tuning of the Zumaia section has recently been obtained. This is extended further back in time by correlation to the Sopelana section by recognition of orbital patterns and marker beds. The total amount of time represented by the two sections is 5 Myr. The lower boundary falls within chron C32N1n, almost reaching the Campanian/Maastrichtian boundary. Magnetostratigraphic and biostratigraphic data allow for application of the cyclostratigraphic framework worldwide, and comparison to previously published Maastrichtian time scales. Additionally, we present an orbitally tuned bulk carbon isotope curve. The high resolution and large amplitude of shifts in δ13C on the 405-kyr and 1.2-Myr scales enables correlation to deep marine oceanic sites, several sections from the Boreal chalk sea and Italy and, importantly, the Campanian/Maastrichtian boundary GSSP at Tercis, France. This will provide a globally applicable cyclostratigraphic framework for the entire Maastrichtian. We will discuss the implications for the orbital pacing theory of the late Cretaceous climate system. Furthermore we will elaborate on the enigmatic presence of a strong 1.2-Myr cyclicity in lithological and proxy record data and its possible relation to carbon cycle dynamics and/or orbital forcing.