Geophysical Research Abstracts
Vol. 14, EGU2012-8551, 2012
EGU General Assembly 2012

Carbon cycles in Late Cretaceous time

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A refined astronomical tuning of the upper Albian-lower Campanian record is proposed from the Tethyan pelagic sedimentary sequence of the Bottaccione reference section (Umbria-Marche Basin, central Italy). Long-term eccentricity cycles filtered from a new high-resolution bulk sample δ^{13}C signal were tuned to the highly stable 405 kyr cycles of the insolation target curve. Application of integrated methodologies of non-stationary/non-linear signals analysis (Intrinsic Mode Functions, WWZ Wavelet, non-linear filtering techniques, etc.) provided reliable numerical tools to explore the highly complex $\sim$23 Myr long record. Exploration of the hierarchical pattern organization of lithology in selected parts of the sedimentary record provided an important constrain for the tuning strategy. The proposed orbital tuning provides a new and accurate age model for dating biostratigraphic, magnetic and carbon isotope events. Moreover, the exploration of long-term cycles ($\sim$1.2 to $\sim$7.1 Myr) in the δ^{13}C signal throughout the entire record offers an unprecedented chance to investigate processes associated to global carbon cycle dynamics and response to orbital forcing, biogeochemical cycles and sea level changes. Long-term eccentricity cycles of $\sim$2.5 Myr beat the $\sim$23 Myr long record although a direct control of this long–term eccentricity component on the deposition of sediments identified throughout the succession and coeval to the Bonarelli and mid-Cenomanian anoxic events can be unequivocally excluded. During the Turonian-Coniacian stratigraphic intervals, cycles of 1.2 Myr primarily modulate the δ^{13}C curve , fuelling the debate on the potential role of glacio-eustacy on the carbon cycle during short-intervals of this super-greenhouse period. Finally, cycles of $\sim$7.1, 4.5 and 3.2 Myr modulate the entire δ^{13}C record and represent primary very long-term oscillation modes of Earth's climate-ocean system. Although an ultimate driver of these long-term periodicities is lacking we speculate that the 4.5 and 2.5 Myr cycles documented in the Late Cretaceous represent homologues of the present eccentricity grand cycles evolved by chaotic behaviour of solar planets during the Mesozoic. They could represent appropriate system low-frequency means for geological correlation and robust constraints on the orbital evolution of the Solar System.