Integrating Multiple Clocks and their Applications in Geology and Astronomy

CHAO MA[1], STEPHEN R. MEYERS[2] AND BRADLEY B. SAGEMAN[3]

[1] Department of Geoscience, University of Wisconsin-Madison, WI 53706. chao.ma@utah.edu
[2] Department of Earth and Planetary Sciences, Northwestern University, IL 60208. smeyers@geology.wisc.edu
[3] University of Utah, Department of Geology and Geophysics, Salt Lake City, UT 84112. b-sageman@northwestern.edu

Geochronology provides a critical foundation for studies of Earth history. The field includes a spectrum of techniques such as radioisotopic dating, magnetostratigraphy, biostratigraphy, chemostratigraphy, and astrochronology. Each method has pros and cons: radioisotopic dating provides numerical age data, but is subject to uncertainties related to phenocryst formation and integrity, as well as analytical methodology. Magnetostratigraphy, biostratigraphy and chemostratigraphy provide useful relative time markers, but they are discrete and their age must be interpolated from radioisotopic data. Astrochronologic reconstructions yield a continuous time scale that can be linked to astrophysical models anchored in the modern, but only for time periods younger than about 50 Ma; older astrochronologies are floating and require radioisotopic dates to anchor them. Integrating such methods provides a comprehensive system to reconstruct robust geological time scales and astrochronology is playing an increasingly important role in the integration. As astrochronologic studies expand, there are more opportunities to unravel paleoclimate dynamics, as well as the history of celestial mechanics. Although the theoretical astrophysical solutions are the foundation of astrochronology, beyond 50 Ma the solutions are highly sensitive to initial conditions, so it becomes difficult to calculate precisely – due to the chaotic behavior of the solar system – resulting in a wide spectrum of possible orbital solutions. The 2.4-Myr eccentricity cycle, which reflects the secular resonance between the precession of the perihelion of the Earth and Mars, is a feature that can be preserved in long rhythmic sedimentary records and used to constrain the chaotic behavior of the solar system. This study presents a composite orbitally influenced sedimentary record from the Western Interior Seaway during the Late Cretaceous (82-97 Ma). Geological data are anchored with a high resolution time scale incorporating cyclostratigraphy and radioisotopic geochronology. The long period signatures of secular resonance were extracted from the primary records and the disappearance of the 2.4 Myr cycle between 97 Ma and 82 Ma is interpreted to reflect an interval of chaotic behavior in the paleo-solar system. This macroscopic feature of the cyclostratigraphic record makes it possible to discriminate among different orbital solutions. The result compares well with one of the orbital solutions proposed by Laskar et al. (2004). The record provides important geological evidence for constraining the behavior of the solar system during Earth history.