Astronomical Dating and the Quest for a Stable Geological Time Scale

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Sedimentary archives can be dated by matching patterns of paleoclimate variability with patterns of varying solar energy input computed from the astronomical model solutions. This astronomical tuning of the sedimentary record results in time scales based on measurable physical parameters that are totally independent from those underlying radio-isotopic dating and that are tied to the Recent through a direct match with astronomical curves. Astronomical tuning is at present the most accurate absolute dating technique for the youngest part of the Earth's history, the success and validity of the approach being demonstrated by the adoption of the astronomical time scale (ATS) as the standard for the Pliocene and Pleistocene.

Stability in chronostratigraphic standards and chronometric time scales needed to facilitate communication between earth scientists is achieved because astronomical time scales attain a permanent character, thus avoiding the promulgation of new and fundamentally different time scales. An important additional advantage is that recently defined chronostratigraphic boundaries are directly tied to the astronomical time scale via first-order calibrations in the Mediterranean.

Here we will give a historical review of the ATS. After this introduction we will focus on the Mediterranean late Neogene. Important aspects are: 1) the incorporation of the continental record to allow for detailed correlations between the marine and continental realm, 2) the intercalibration of the independent astronomical and radiometric dating methods via a direct comparison of astronomical and Ar/Ar ages of ash layers, 3) the closure of the Messinian gap having major implications for the timing and origin of the salinity crisis in the Mediterranean, and 4) the testing of different astronomical solutions through comparison with sedimentary cycle patterns.

Application of the ATS provides better constraints on the dating of short magnetic reversal excursions and reversals, tectonic pulses and rotations, evolutionary changes, biochronology and faunal turnovers, and long-term variations in lithology, such as third-order sequences. But it also gives highly accurate ages for important chronostratigraphic boundaries such as the base of the Pliocene at 5.333 Ma and the base of the Pleistocene at 1.806 Ma. A major reason for developing astronomical time scales, however, is their applications in paleoclimatic and paleoceanographic studies, in particular those directed at deciphering the intricate relationships between astronomical forcing and climate response, and their recording in sedimentary archives.

Ongoing and future research will be directed to develop a similar permanent astronomical time scale for the entire Cenozoic and Mesozoic.