

Early Permian (Cisuralian) time scale,
and pan-Euramerican chronostratigraphic
correlation

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A quantitative biostratigraphic and radiometric calibration is presented for the Mississippian through Early Permian global time scale, based upon high-precision IDTIMS U-Pb zircon ages for interstratified ash beds in the paralic Carboniferous successions in Donets Basin and from type sections of the southern Urals of Russia. In Donets Basin zircon ages for twelve tuffs are used to radiometrically calibrate the detailed litho-, cyclo- and biostratigraphic framework. Chemical abrasion of zircons, use of the internationally calibrated EARTHTIME mixed U-Pb isotope dilution tracer, and improved mass spectrometry guided by detailed error analysis have resulted in an age resolution of $< 0.05\%$, or *ca* 100 ka. This precision allows the resolution of time in the Milankovitch band, and confirms the long-standing hypothesis that individual highfrequency Pennsylvanian cyclothems and bundles of cyclothems into fourth order sequences are the eustatic response to orbital eccentricity (*ca* 100 and 400 ka) forcing. Tuning of the fourth order sequences in the Donets Basin to the long-period eccentricity cycle results in a continuous age model for the middle to late Pennsylvanian (Moscovian-Kasimovian-Ghzelian) strata of the basin and their record of biological and climatic changes through the latter portion of the Late Paleozoic Ice Age. Twenty-four ash bed ages in three outer ramp and basinal sections of the Pre-Uralian foredeep bracket the biotic definitions of global stages and regional substages from the base of the Upper Pennsylvanian Kasimovian Stage to the base of the Lower Permian Artinskian Stage; four additional ash bed ages constrain the global Bashkirian and Serpukhovian Stages.

Quantitative stratigraphic methods (CONOP9) are applied to a compilation of over 2600 bioevents in 28 stratigraphic sections supplemented by our dated volcanic horizons to refine the Mississippian-Early Permian global time scale. The unprecedented density of radiometric calibration points for the Pennsylvanian-Permian transition provides a highresolution (~ 0.1 Ma) global chronostratigraphic standard for testing and improving biostratigraphic correlations across Euramerica. We integrate radiometric ages, biostratigraphic correlation, and cyclostratigraphic tuning of major cyclothems to the long period (404 ka) eccentricity cycle to elucidate the tempo, magnitude, and forcing of eustatic changes and cyclothem deposition associated with the waxing and waning of Gondwanan ice sheets, and establish a pan-Euramerican chronostratigraphic framework for most of Pennsylvanian and Early Permian time.

Uppermost Devonian and Mississippian
sequence stratigraphy and rugose coral
biostratigraphy of Zonguldak and Bartın area,
NW Turkey

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The Mississippian succession of Zonguldak and Bartın area in Northwestern Turkey, known from several sections, shows typical shallow-water shelf carbonate facies. The lithostratigraphy of this area is re-studied and re-interpreted for the sequence stratigraphy. Dating and correlation are mainly based on rugose coral biostratigraphy, completed by foraminifer biostratigraphy. Almost all Mississippian rugose coral biozones defined in Western Europe are identified in Turkey, especially in the Viséan. The third order sequences known in Europe are also recognized. The lowermost part the Kışla Fm is the oldest fossiliferous unit of Zonguldak and Bartın areas. It yields stromatoporoids, quasiendothyrid forams and rugose corals typical of the RC0 biozone of Poty et al. (2006) and indicating a Strunian (Latest Devonian) age. It corresponds to the TST of the third order sequence 1 of Hance et al. (2001). The upper part of the Kışla Fm and the lower part of the overlying Ulutam Fm show very shallow-water facies almost devoid of coral. This succession is not dated and the sequences are not specified. The oolitic limestone of the upper part of the Ulutam Fm is identified as the HST of the sequence 4 and yields uppermost Tournaisian fauna. The topmost part of the Ulutam Fm is thought to correspond to the lowermost Viséan because the overlying Kokaksu Fm yields typical Moliniacian (lower Viséan) fauna. Among them, the rugose corals *Dorlodotia briarti* and *Siphonodendron ondulosum* are the guide taxa for the RC4 β and RC5 α biozones respectively. The middle and upper parts of the Kokaksu Fm are the most fossiliferous units. They yield typical Livian and Warnantian (middle-late Viséan) fauna from RC5 β to RC7 β biozones, among which *Siphonodendron martini*, *S. pauciradiale*, *S. asiaticum*, *Lithostrotion araneum*, *L. vorticale*, *Clisiophyllum garwoodi*, *Haplolasma* sp. *Caninophyllum archiaci*, *Palaeosmia murchisoni*, *Aulophyllum fungites*, etc. At least two sequences are recognized in the formation, namely sequences 7 and 8. The topmost beds of the Kokaksu Fm yield Brigantian (uppermost Viséan) corals as *Nemistium* sp. and *Palastraea* sp., indicating the RC8 biozone. The overlying Dört Degirmen Fm is made of shale and sandstones containing plant remains but also rare limestone intercalations that yield several brachiopods and foraminifers indicating an uppermost Viséan age.