Modern-style plate tectonics began in Neoproterozoic time: An alternative interpretation of Earth's tectonic history

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ABSTRACT

Modern-style plate tectonics are mostly driven by the excess density of oceanic lithosphere sinking deeply in subduction zones and can be sustained as long as melt is produced at mid-ocean ridges. Among the silicate planets, the mechanism of plate tectonics is unique to Earth, indicating that special circumstances are required. Given that the potential temperature of Earth's mantle has decreased by several hundred degrees Celsius since Archean time, the density of oceanic lithosphere must have systematically increased, which has profound implications for the viability of plate tectonics through time. Two things must be done to advance our understanding of Earth's tectonic history: (1) uncritical uniformitarianism should be avoided; and (2) the geologic record must be thoughtfully and objectively interrogated. Theoretical considerations should motivate the exploration, but geologic evidence will provide the answers. The debate needs to address the criteria for identifying tectonic style in ancient rocks, whether this evidence is likely to be preserved, and what the record indicates. The most important criteria are the temporal distribution of ophiolites, blueschists, ultrahigh-pressure terranes, eclogites, paired metamorphic belts, passive margins, subduction-related batholiths, arc igneous rocks, isotopic evidence of recycling, and paleomagnetic constraints. This list of criteria should evolve; objective redefinitions and reviews of, especially, the eclogite paired metamorphic belt and subduction-related batholith records are needed. Also, the likely effects of major tectonic changes on other Earth systems should be considered, such as true polar wander, climate change, and biosphere changes. The modern episode of plate tectonics began in Neoproterozoic time, <1.0 Ga ago, with earlier alternating episodes of proto-plate tectonics (1.8-2.0 and 2.5-2.7 Ga); unstable stagnant-lid tectonics dominated the rest of Proterozoic time and an unknown part of Archean time.