Stratigraphic, geochronological, and paleomagnetic constraints upon the Neoproterozoic climatic paradox

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Abstract

Of the many models that have been proposed to account for the enigmatically widespread and apparently low-latitude Neoproterozoic glaciogenic deposits, three are widely considered: (1) the Phanerozoic archetype of glaciated polar regions and mid-latitudes only, (2) the "Snowball Earth" model with globally synchronous glaciations, and (3) the high-obliquity hypothesis. These models respectively predict purely high-to-moderate paleolatitudes, all paleolatitudes, and preferentially low paleolatitudes of glacial deposits. To distinguish among these alternatives, I present a thorough compilation of the Neoproterozoic glacial deposits and their current age constraints, avoiding intercontinental correlations in almost all cases. In this conservative view, paleomagnetic data are relevant only if directly measured upon the glaciogenic deposits or conformable units, or if the glaciogenic formations are precisely dated enough for application of equally well dated paleomagnetic poles from the same craton.
The primary conclusion to be drawn from this compilation is that very few of the deposits have reliable paleomagnetic constraints. Of that subgroup, however, low latitudes are more common than one would expect if randomly drawn from a uniform distribution on the sphere. Not a single high-paleolatitude (poleward of 60°) deposit has been documented convincingly. Both the "Snowball Earth" hypothesis and the high-obliquity model are permitted by the present paleomagnetic dataset. The Phanerozoic archetype fails to account for robust determinations of near-Equatorial paleolatitude from several Neoproterozoic glaciogenic deposits. If a non-uniformitarian model such as the high-obliquity hypothesis is correct, then its transition to the Phanerozoic archetype must have occurred rapidly, near the beginning of Cambrian time. Alternatively, if the Snowball Earth model is correct for Precambrian time then the lack of tropical glaciations since 550 Ma may be fortuitous or may indicate secular changes in the boundary conditions or processes governing surficial conditions on planet Earth.