



Constraining the margins of Neoproterozoic ice masses: depositional signature, palaeoflow and glaciodynamics

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The scale and distribution of Neoproterozoic ice masses remains poorly understood. The classic Snowball Earth hypothesis argues for globally extensive ice sheets, separated by small ocean refugia, yet the positions of palaeo-ice sheet margins and the extent of these open water regions are unknown. Abundant evidence worldwide for multiple cycles of ice advance and recession is suggestive of much more dynamic mass balance changes than previously predicted. Sedimentological analysis enables an understanding of the changing ice margin position to be gained through time, in some cases allowing it to be mapped. Where the maximum extent of ice advance varies within a given study area, predictions can also be made on the morphology of the ice margin, and the underlying controls on this morphology e.g. basin configuration. This can be illustrated using examples from the Neoproterozoic Kingston Peak Formation in the Death Valley region of western USA. Throughout the Sperry Wash, northern Kingston Range and southern Kingston Range study sites the successions show evidence of multiple cycles of ice advance and retreat, but the extent of maximum ice advance is extremely variable, reaching ice-contact conditions at Sperry Wash but only ice-proximal settings in the most distal southern Kingston Range. The overall advance is also much more pronounced at Sperry Wash, from ice-distal to ice-contact settings, as compared to ice-distal to ice-proximal settings in the southern Kingston Range. Therefore, the position of the ice margin can be located at the Sperry Wash study site, where the more pronounced progradation is used to argue for topographically constrained ice, feeding the unconstrained shelf through the northern into the southern Kingston Range. This raises the question as to whether Neoproterozoic ice masses could be defined as topographically constrained ice caps, or larger ice sheets feeding topographically constrained outlet glaciers.