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Tides: a driver for the early evolution of terrestrial vertebrates?

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Only once in Earth's history, ∼393 Ma (Ma = million years), have vertebrates made the transition from a marine to terrestrial environment. The earliest bony fish (osteichthyan) fossils occur in South China during the Late Silurian (425 Ma), with the earliest evidence of tetrapods in the form of trackways occurring in Laurussia during the Early Middle Devonian (393 Ma). The environment during the Late Silurian to Early Middle Devonian was rapidly changing and so it is therefore likely that there were several factors involved in the radiation of osteichthyans that gave rise to terrestrial tetrapods. Here, we explore the possibility that large tidal ranges may have fostered the evolution of air-breathing organs in osteichthyans, as fish stranded in tidal pools as part of a substantially large upper intertidal zone would be subjected to prolonged hypoxic conditions. Large tidal ranges could also have been an impetus for the development of chirdian limbs in tetrapods for navigation within extensive intertidal zones. Indeed, many of the earliest fossils of tetrapods, and the transitional forms known as 'elpistostegids' (e.g. Panderichthys, Elpistostege), are found in deltaic sediments. We have used recent global palaeogeographic reconstructions for the Late Silurian (420 Ma) and Early Middle Devonian (400 Ma) in a state-of-the-art numerical tidal model, OTIS, to produce a series of tidal simulations. We evaluated the two dominant components of the tide: the principal lunar constituent (M2) to evaluate whether large tidal ranges occurred, and the principal solar constituent (S2) (hereafter referred to as the spring-neap range) to explore the spring-neap range variability. Macro-tidal M2 ranges (i.e. a tidal range over 4 m) coincided with large spring-neap ranges in simulations for both time slices, suggesting that a large upper intertidal zone existed in several areas. This was most apparent around the coastlines of the South China and Indochina blocks for the 420 Ma control simulation, showing large tidal variability during the origin of Osteicthyes. These ranges are comparable to Present day tides, which is postulated to be in a tidal maxima period. These results highlight the probable importance of tidal dynamics in driving early vertebrate evolution.