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Trilete spores from the Ordovician of Saudi Arabia: earliest evidence for vascular plants and their immediate predecessors (“protracheophytes”)

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The invasion of the land by plants (embryophytes) is considered to have occurred in a step-wise fashion. The earliest noncontroversial fossil evidence for land plants is from the Middle Ordovician and consists of dispersed spores. These spores are termed cryptospores because they occur in unusual configurations, although they do bear similarities to the spores of certain extant bryophytes. They are considered to represent a flora of stem group embryophytes that possessed bryophyte-like anatomy and physiology. Cryptospore assemblages are palaeogeographically widespread and exhibit stasis for approximately 40 million years, showing remarkably little temporal and spatial variation. The bryophyte-like stem group embryophytes were probably generalists that could tolerate a wide variety of climates. A major change in dispersed spore assemblages is documented in the Late Ordovician (Ashgill)-Early Silurian (Llandovery) when trilete spores appear. Early occurrences are sparse with simple trilete spores forming a very minor component of dispersed spore assemblages. However, in the late Llandovery trilete spores diversify in terms of abundance, diversity and disparity concomitant to a dramatic decline in cryptospore abundance. Trilete spores are characteristic of primitive vascular plants (fossil and extant) and their extinct immediate precursors (“protracheophytes”). The change in spore assemblages is interpreted as representing the origin of this group of plants that initially were rare and diversified little (slow fuse) but then underwent a dramatic and rapid diversification in terms of abundance, diversity and disparity (adaptive radiation). During this radiation they outcompeted the bryophyte-like stem group embryophytes, although this group of plants probably gave rise to the extant bryophyte groups (but always as a minor component of the land flora subsidiary to the better adapted vascular plants). Here we report on an important new trilete spore occurrence from Mid-Late Ordovician rocks from Gondwana. This is the earliest to date and is surprisingly diverse (4-5? taxa) including laevigate and ornamented species. It suggests that the origin and diversification of vascular plants exhibited a slightly different pattern than previously envisaged. It seems likely that vascular plants appeared earlier on Gondwana before spreading to other continents. Based on the position of Gondwana at this time, these findings hint at the intriguing possibility that vascular plants may have evolved at high southern latitudes before migrating northwards and eventually diversifying.