

Original article

Palaeoenvironmental setting (glaciations, sea level, and plate tectonics) of Palaeozoic major biotic radiations in the marine realm

Cadre paléoenvironnemental (glaciations, niveau marin et tectonique des plaques) des radiations biologiques majeures du Paléozoïque en domaine marin

Dmitry A. Ruban*

*Division of Mineralogy and Petrography, Geology and Geography Faculty, Southern Federal University,
Zorge Street 40, 344090 Rostov-na-Donu, Russian Federation*

Available online 28 June 2011

Abstract

The life on the Earth experienced periodically not only significant impoverishments (mass extinctions), but also remarkable rises in diversity. Two recent biodiversity curves and new information on glaciations, sea-level, and plate tectonics, permit to extend our knowledge on the latters. Four Palaeozoic major radiations in the marine realm are identified. They include the early Cambrian (PZMR1), Ordovician (PZMR2), Early Devonian (PZMR3), and mid-Permian (PZMR4) events. PZMR1 occurred immediately after the major end-Proterozoic glaciations, when global sea-level rose with low-magnitude fluctuations and huge well-connected oceans provided a peculiar space for biological innovations. PZMR2 happened at a time of unique sea-level highstand and well-connected watermasses. PZMR3 coincided with a relative sea-level lowstand, which, together with the presence of elongated island chains, might have enhanced the radiation by a rapid dispersal of organisms across shallow oceans and along connected shorelines. PZMR4 occurred at the end of the outstanding planetary-scale Late Palaeozoic glaciation. Generally, the Palaeozoic major radiations in the marine realm did not have an ultimate cause and did not occur in a similar palaeoenvironmental setting. The molecular clock approach suggests a possible link between the DNA-dated divergences of marine invertebrates and the identified major radiations.

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Keywords: Marine biodiversity; Radiation; Glaciation; Global sea level; Plate tectonics; Molecular clock evidence; Palaeozoic

* Corresponding author. PO Box 7333, 344056, Rostov-na-Donu, Russian Federation.

E-mail addresses: ruban-d@mail.ru, ruban-d@rambler.ru

Résumé

La vie sur Terre a non seulement périodiquement connu des chutes (extinctions en masse), mais aussi des augmentations remarquables de sa diversité. Deux courbes récentes de la biodiversité ainsi que de nouvelles informations sur les glaciations, le niveau marin et la tectonique des plaques, permettent de compléter nos connaissances sur ces radiations. Quatre radiations majeures du Paléozoïque sont identifiées dans le domaine marin. Elles comprennent les événements du Cambrien basal (PZMR1), de l'Ordovicien (PZMR2), du Dévonien basal (PZMR3) et du Permien moyen (PZMR4). PZMR1 a débuté immédiatement après les glaciations majeures de la fin du Protérozoïque, quand le niveau marin global augmenta avec des fluctuations de faible amplitude et que les océans bien interconnectés ont fourni un espace propice pour les innovations biologiques. PZMR2 s'est produite lors d'une période de remarquable haut niveau marin et de masses d'eau bien interconnectées. PZMR3 a coïncidé avec un bas niveau marin relatif, qui, avec la présence de chaînes d'îles allongées, aurait favorisé la radiation par une dispersion rapide des organismes à travers des océans peu profonds et le long des lignes de rivage connectées. PZMR4 a eu lieu à la fin de la dernière glaciation paléozoïque majeure à l'échelle globale. De manière générale, les radiations majeures du Paléozoïque n'ont pas eu une cause définitive et ne se sont pas produites dans des contextes paléoenvironnementaux similaires. L'approche par l'horloge moléculaire suggère un lien entre les divergences datées grâce à l'ADN chez les invertébrés marins et les radiations majeures identifiées.

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Mots clés : Biodiversité marine ; Radiation ; Glaciation ; Niveau marin global ; Tectonique des plaques ; Horloge moléculaire ; Paléozoïque

1. Introduction

Significant fluctuations of biodiversity occurred throughout the Palaeozoic Era (Alroy et al., 2008; Purdy, 2008) (Fig. 1). However, mass extinctions have received more attention than major biotic radiations. The Cambrian biodiversity “explosion” (Brasier, 2009; Conway Morris, 1998, 2000, 2003; Geyer, 1998; Kirschvink and Raub, 2003; Lieberman, 2008; Zhuravlev and Naimark, 2005) and the Great Ordovician Biodiversification (Connolly and Miller, 2001, 2002; Droser and Sheehan, 1995; Droser et al., 1996; Harper, 2006; Masuda and Ezaki, 2009; Miller and Connolly, 2001; Miller and Foote, 1996; Sepkoski and Sheehan, 1983; Servais et al., 2008, 2009, 2010; Webby, 2001) are the only events to have been discussed more or less in the same way that biotic catastrophes. Few other important time intervals, when life flourished, were reviewed rarely (Powell (2005) for information on the Late Palaeozoic radiation). When the nomenclature of mass extinctions is well developed (Bambach, 2006; Bambach et al., 2004; Benton, 1995; Hallam, 2005; Hallam and Wignall, 1997; Raup and Sepkoski, 1982; Sepkoski and Raup, 1986), there is no any similar framework for major radiations. Intrinsic (evolutionary, biological) factors of biodiversity changes, including radiations, have been discussed quite well, at least for some time intervals (Brasier, 2009; Connolly and Miller, 2001; Servais et al., 2010; Stanley, 2007; Munnecke et al., 2010). However, extrinsic (palaeoenvironmental) factors of radiations (including those Cambrian and Ordovician) are debated a bit less intense than those of mass extinctions (Alvarez, 2008; Courtillot, 2007; Erwin, 2006; Hallam, 2005; Hallam and Wignall, 1997, 1999; Lieberman and Kaesler, 2010; Racki, 2005; Ruban, 2009; Twitchett, 2006; Wignall, 2001, 2004).

The purposes of this paper are: a definition of Palaeozoic major radiations in the marine realm on the basis of recent biodiversity reconstructions (Alroy et al., 2008; Purdy, 2008) and; an

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