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Did the primary productivity trigger the Early Palaeozoic biodiversification?

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Diversification of the marine biosphere is intimately linked to the evolution of the biogeochemical cycles of carbon, nutrients, and primary productivity. Evolving food quantity and quality was primarily a function of broad tectonic cycles that influenced not just carbon burial, but also nutrient availability and primary productivity (STILLMAN 1984, BAMBACH 1993, MILLER & MAO 1995, MARTIN *et al*. 2008). Primary production (PP) and phytoplankton in the surface ocean are the base for almost all marine food webs. PP is influenced by the intensity of light and the availability of the most important, i.e. nitrogen and phosphorus (FALKOWSKI 2002, STROTHER 2008). The Early Palaeozoic biodiversification could have been provoked by a sudden increase of nutrient supply and of primary productivity (VERMEIJ 1987). At that time, excluding changes in ocean dynamics, the nutrient cycling was probably only influenced by the geodynamics events such as volcanicity and orogeneses, because of the quasi-absence of land plants (SIGNOR & VERMEIJ 1994, SERVAIS *et al*. 2008, STROTHER 2008). The main goal of this work is to test the hypothesis of the impact of the primary productivity on the diversity increase of benthic fauna during the most important biodiversification event of the Phanerozoic.

The estimation of the primary productivity is based on the fluctuations of the modelled phosphorus cycle (FROELICH *et al*. 1982, SHAFFER 1989, DELANEY 1998). Phosphorus (P) could be the most limiting nutrient in oceans (VAN CAPPELLEN & INGALL 1994, FALKOWSKI 2002, WALLMANN 2003). P cycle has been modelled using a numerical model simulating the climate and global biogeochemical cycles (GEOCLIM; DONNADIEU *et al*. 2006). Input in P cycle depends on continental weathering, on the type of exposed rocks, palaeogeography, and climate (FROELICH *et al*. 1982, DELANEY 1998, FILLIPELLI 2002). Output in P cycle corresponds to the authigenic apatite formation and burial, the hydrothermal particulates, the adsorbed and oxyhydroxide-associated P deposition, and the P uptake in marine organisms (FROELICH *et al*. 1982, FÖLLMI 1996, WHEAT *et al*. 1996, DELANEY 1998, PETSCH & BERNER 1998, BJERRUM & CANFIELD 2002).

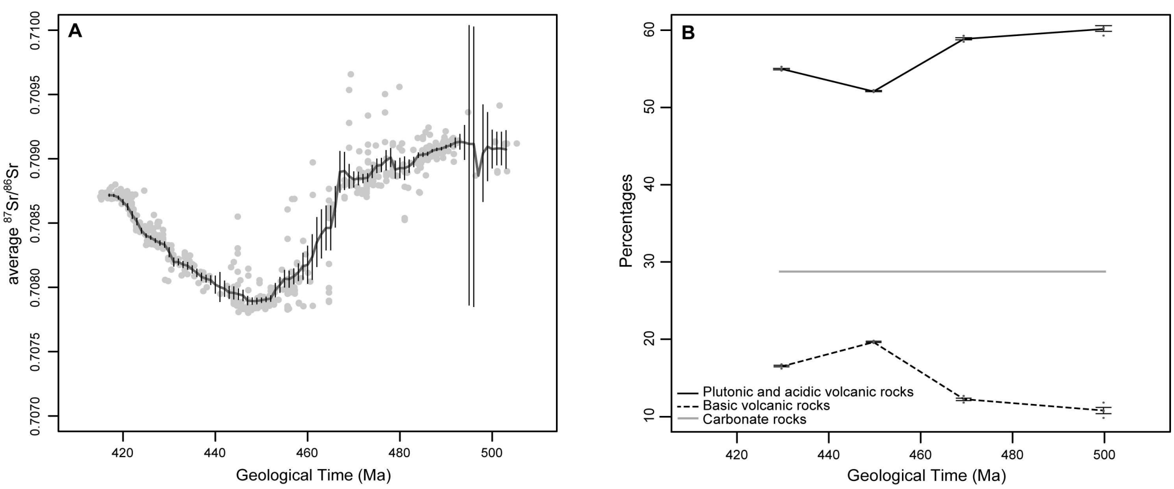

Fig. 1A: Raw experimental values of 87Sr/86Sr (grey points) and their mobile mean over 6Ma with confidence intervals (red and black lines, respectively); data from Veizer *et al*. 1999. 1B: Percentage of basic volcanic rocks (dashed black line), carbonate rocks (grey line), and plutonic and acidic volcanic rocks (raw black line) outcropping on Earth calculated using GEOCLIM.

The Sr isotopic composition of seawater can be utilized as a proxy parameter for tectonic events on Earth. $^{87}Sr/^{86}Sr$ ratio fluctuations reflect the balance between the continental and mantle fluxes of Sr (FAURE & POWEL 1972, VEIZER *et al*. 1999). As we consider the mantle activity as constant through time, the fluctuations of the $^{87}Sr/^{86}Sr$ ratio are controlled by the isotopic composition of riverine water, constrained by continental rock weathering. Using the average $^{87}Sr/^{86}Sr$ ratio values (Fig. 1A), we modelled with GEOCLIM, the proportion of the two main types of rocks (Plutonic and acid volcanic (0.718), and Basic volcanic rocks (0.7035)) with the proportion of carbonate rocks considered as constant (0.708; 29% as present values; DESSERT *et al*. 2003), on Earth for the Furongian (500Ma), the lowermost Middle Ordovician (470Ma), the Late Ordovician (450Ma) and the uppermost Llandovery (430Ma). Based on these results we then have calculated the Phosphorus content in oceans at each period of time. As P input depends on the dissolution of the apatite present in exposed rocks on Earth, the numerical model of chemical weathering in soil horizons and underlying bedrock (WITCH) was used to test the continental P input (GODDÉRIS *et al*. 2006).

Preliminary results show a relatively high proportion of plutonic and acidic volcanic rocks on Earth during the Furongian, lowermost Ordovician and Silurian. This proportion decreases during the Ordovician to reach a low level during the late Ordovician, concomitant with the gradual rise of basic volcanic rocks (max 20%, Fig. 1B). This trend is consistent with the observed increase of the K-bentonites extension during Ordovician (HUFF 2008). Modelled rocks erodability tests evidence a better discharge of phosphorus by the weathering of basic volcanic rocks (up to 1.5 more than the plutonic rocks weathering). We expect a possible increase of phosphorus release during the late Cambrian-lowermost Ordovician followed by a slight decrease. This could be consistent with the diversity signals of the main taxonomic groups during the Early Palaeozoic, which show a gradual increase until the uppermost Middle Ordovician and then a more or less abrupt decrease during the Upper Ordovician (SERVAIS *et al*. 2008).

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