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Did India-Asia plate velocity increase and Neo-Tethys closure contribute to the Early Eocene Climatic Optimum?

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The 60-50 Ma interval was characterized by a long-term increase of global temperatures (+4 to +6˚C), which culminated during the Early Eocene Climatic Optimum (EECO, 53-50 Ma), the warmest interval of the Cenozoic [1]. Geochemical proxies and modelling claim high CO_2 atmospheric concentrations prevailing at this time [e.g., 2]. Processes explaining sustained high greenhouse gas concentrations may relate either to volcanic degassing (NAIP, [3]) or to CO_2/CH_4 release during metamorphism in extensional (NW American Cordillera [4]) or compressional tectonic regimes (India-Asia collision, [5]; Gulf of Alaska, [6]). More recently, it has been suggested that Tethyan closure may have strongly controlled Cretaceous and Eocene climates, through the subduction of large amounts of pelagic carbonates and their recycling as CO_2 at arc volcanoes ("subduction factory") [7,8,9]. In order to detail the impact of the Tethys closure on the EECO, we have built a model to calculate the volume of subducted sediments and the amount of CO_2 and CH_4 emitted at active arc volcanoes along the northern Tethys margin. The model takes into account the sediment thickness, carbonate and organic matter content, the mean subduction velocities of the Indian, Arabian and African plates and the decarbonation efficiency at arc volcanoes. The effect of the India-Asia collision was also modelled using a simple Indian passive margin geometry. Our first results indicate that the mean subduction rate (controlling the volume of subducted sediments) increased from 4.5 cm/yr on late Maastrichtian to a maximum value of 7 cm/yr during the EECO, mainly owing to a dramatic India-Asia plate convergence increase. If a minimal decarbonation efficiency at arc volcanoes of 20% is considered, pelagic carbonate-rich sediments ($CaCO_3$ = 90 wt%) must reach a minimal thickness of 450 m to allow the release of 10^{18}mol/Ma between 60 and 50 Ma, a minimal value to account for Late Paleocene/Early Eocene warming [10]. A decarbonation efficiency of 50% [9] would lower sediment thickness to 180 m, a plausible value given the subtropical location of northern Tethys during much of its closure history [8]. The arrival of the Indian continental margin in a subduction zone, and the related dramatic increase of passive margin carbonate subduction may also increase the production of CO_2 by up to a factor of three. On the other hand, for all scenarios the amount of CH_4 falls in the range of 0.2-10 MtCH_4/yr, 1-2 orders of magnitude below background fluxes. These results strengthen arguments for the role of the Tethyan subduction in contributing to Late Paleocene/Early Eocene greenhouse conditions through CO_2 production. The "subduction factory" was in play coevally with other important CO_2 sources such as the NW American cordillera or mantle plume – sediment interaction [11], calling for a multi-causal warming.

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