Temporal and genetic link between large igneous provinces and black shales during "Earth's middle age"

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Phanerozoic large igneous provinces (LIPs) have a significant influence on global climate changes and mass extinctions [1-3]. Most of the Global Boundary Stratotype Section and Points (GSSPs) in the Phanerozoic international chronostratigraphic scale are coeval with global-scale LIPs and are marked in the sedimentary record by mass extinction events and/or by ocean anoxic events (OAEs) represented by black shales [3,4]. However, due to limited knowledge and controversies on atmospheric oxygen concentrations, ocean redox conditions and early fossils during the Meso-Neoproterozoic Era prior to the Ediacaran period [5-7], little is known on the climate and environmental effects of LIPs during this period. Here we present solid evidence for a temporal and genetic link between the remarkably intense *ca.* 1380 Ma LIP activity and coeval black shales in the Nuna supercontinent. We also propose that the *ca.* 1380 Ma LIPs and black shales widely distributed in the Nuna supercontinent represent a global-scale geological event and provide a robust natural marker for the Calymmian–Ectasian boundary. We explore additional LIP events in "Earth's middle age" (1750–750 Ma) and their possible correlation with black shales and potential implications for subdivisions of the Precambrian international chronostratigraphic scale. Our temporal and genetic link between LIPs and black shales during "Earth's middle age" may also have significant implications for understanding the atmospheric oxygen concentrations and ocean redox conditions during this period.

[1] Marzoli et al. (1999) *Science* **284**, 616–618. [2] Sobolev et al. (2011) *Nature* **477**, 312–316. [3] Ernst & Youbi (2017) *Palaeogeogr Palaeoclimatol Palaeoecol* **478**, 30–52. [4] Percival et al. (2015) *Earth Planet Sci Lett* **428**, 267–280. [5] Canfield et al. (2007) *Science* **315**, 92–95. [6] Lyons et al. (2014) *Nature* **506**, 307–315. [7] Lee et al. (2016) *Nat Geosci* **9**, 417–424.