Hierarchy in mass extinction causes: from direct kill mechanism to ultimate cause

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Causes of extinction can be grouped into four categories in hierarchy, from small to large scale: i.e., Category 1 –direct kill mechanism for each local biota, Category 2 –background change in global environment, Category 3 –major geological phenomenon on the planet’ s surface, and Category 4 –ultimate cause from the interior and exterior of the planet (Isozaki, 2019). Previous discussions on bolide impact and/or LIP are limited solely to Category 3. Bolide fall-out and/or LIP formation have been regarded as accidental phenomena; however, these likely have appeared under strong controls of agents of Category 4. The study of mass extinctions on the Earth is entering a new stage with a new astrobiological perspective. The Paleozoic era experienced 4 major mass extinctions; i.e., end-Ordovician, Late Devonian, end-Guadalupian, and end-Permian episodes. For causing significant biodiversity decline, non-biological environmental change on global scale is needed for a trigger; nonetheless, popular claims on bolide impact and/or large igneous province (LIP) with too much *ad-hoc* assumptions have not yet been accepted as common/universal explanation for the Paleozoic extinctions. New perspectives of cosmoclimatology are emerging for introducing an alternative extinction scenario; e.g. 1) increased flux of galactic cosmic radiation (GCR) and solar/terrestrial responses in planetary magnetism, and 2) encounter with dark nebula. Both can bring profound impacts on Earth’ s climate, in particular, global cooling by extensive cloud coverage and/or dust screen (irradiance shutdown) over the globe. It is noteworthy that the past star-burst events detected in the Milky Way Galaxy by astronomical observations apparently coincide in timing not only with the cooling-associated major extinctions of the Paleozoic (Ordovician, Devonian, and Permian) but also with the Neoproterozoic snowball Earth episodes. Recently our research group detected for the first time the signature of increased flux of extraterrestrial ^{3}He from the slowly accumulated deep-sea P-TB beds immediately below the extinction horizon of the Late Permian radiolarians (Onoue et al., 2019). The same analyses are needed for other extinction cases to prove or disprove this working hypotheses.

References: Isozaki, Y. and Servais, T. (2018) Lethaia 51, 173-186. Doi:10.1111/let.12252. 2018; Isozaki, Y. (2019) In Yamagishi, A. et al., eds. *Astrobiology* 273-301, Springer. doi: 10.1007/978-981-13-3639-3_18; Onoue, T. et al. (2019) Progress in Earth Planetary Science, 6:18. doi:10.1186/s40645-019-0267-0PEPS-D-19-00002.1

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