

## Plume, superplume, plate tectonics, and Earth system

\*Shigenori Maruyama<sup>1</sup>

1. Earth-Life Science Institute, Tokyo Institute of Technology

The Earth is composed of solid planetary system of plate tectonics, plume, superplume tectonics, and growth tectonics in the core with averaged speed of cm-scale per year, except the outer core. The surface of the Solid Earth is covered by thin atmosphere of only 1 bar which is driven by Sun with extremely high-speed hydrological process, indicating the operation of separate system from the solid Earth. Dynamic convection of liquid outer core causes strong bi-polar geomagnetism to protect living organisms on this planet from solar winds and galactic cosmic rays.

Mantle convection in the spherical planets follow the 3D shape as plumes and superplumes from the depth, but it shows platy mode on or near the surface. When the surface is covered by liquid water which plays a critical role to decrease frictional intensity, hence causes the operation of plate tectonics. Plate tectonics provides a mild surface environment on the rocky planet. The three-fold coupling of tectonics, superficial plate tectonics, plume and superplume tectonics in the middle depth, and core tectonics in the deepest place is the cause of the characteristics of habitable planet. One more additional feature for habitability could be a small amount of water on the Earth, by which huge landmass can appear above sea-level.

Superplume operates probably only after 1.0Ga after the formation of the Earth, because of the extensive amounts of slab graveyards can generated and form a supercontinent. Those slab graveyard partially melted to form buoyant restites and sinks of partial melt enriched in FeO to grow anti-crust above CMB.

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