

## The Snowball Earth and emergence of animals

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The earth is still only a habitable planet in the solar system, which is covered with liquid water though geologic time, because the existence of water is assumed as an essential factor for emergence of life. The oldest evidence for existence of ocean is an oceanic plate stratigraphy in the 3.8 Ga Isua supracrustal belt (Komiya et al., 1998). Therefore, the earth spent its long history as a habitable planet at least since then. However, the earth experienced some crises, which the earth was completely covered with ice at several times; namely Snowball Earth events. The most serious events occurred at ca. 750 and 630 Ma, in the Neoproterozoic, named as the Sturtian and Marinoan global glaciations, respectively. The complete of ice cover prevented oxygen-producing photosynthesis and ocean circulation at those times, indicated by large negative anomalies of  $\delta^{13}\text{C}$  of carbonate rocks and occurrence of banded iron formation. In spite of the serious crises of the surface environment, substantial biological evolution followed the Marinoan global glaciation, and animals, possibly bilateralian and radial symmetric animals, and plants appeared after the Snowball earth event. Especially, many fossils including animal embryos, multicellular algae and even fungi, were discovered from ca. 580 Ma phosphorite in Weng'an area of south China.

We study coevolution of surface environment and life after the Marinoan glaciation. Especially, we focused on the determination of species of the adult of the first animal embryos and evolutionary change of composition of the ocean at the time, because the Snowball earth events caused the oceanic chemistry significantly to change due to termination of oxygen-producing photosynthesis at that time and active weathering in the aftermath.

We made geological investigation at seven areas in south China, to reconstruct sedimentary sequence from break-up of the Rodinia Supercontinent to middle Cambrian. In addition, we carried out four excavations in Three Gorge area, and plan another excavation in Weng'an area in this spring to obtain a complete section from 630 Ma Marinoan global glaciation to middle Cambrian. We made chemostratigraphies of composition of rare earth elements (REE) and isotope systematics of carbon, strontium and calcium of carbonate rocks and phosphorite in Weng'an and Three Gorge areas. Estimate of oxygen content of seawater calculated from the Ce content and anomalies indicates that it was suppressed after the Snowball Earth event. The Sr and Ca isotope systematics indicates that shortage of Ca ion of seawater due to onset of Ca biomineralization followed its surplus due to very active continental weathering just after the Snowball Earth event. We analyzed Ca isotopic composition of the oldest (ca 580 Ma) animal embryos to determine the species of the adults, and discovered clear isotopic fractionation between phosphate minerals of the animal embryos and the host dolomite and phosphorite. The difference is consistent with first appearance of Ca-biomineralization at that time, and with a marine snail as the precursor of adult of the animal embryos.