

Temperature reconstruction in the late Pleistocene using fossil terrestrial snails and a stalagmite from an archaeological cave in Okinawa

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Freshwater snails are useful for a paleoclimate proxy. For example, stable oxygen isotope composition of mollusk' s aragonite shells depends on temperature and oxygen isotope composition of water at the time of their growth. The Ryukyu Island Arc, bounded by the East China Sea to the northwest and by the Pacific Ocean to the southeast, is an important area in climatology because its environment is highly associated with the East Asian monsoon (EAM), typhoon, and the Kuroshio current. However, terrestrial paleoclimate records such as tree rings and stalagmites are little in the Ryukyu Island Arc unlike the East Asia Continent. Meanwhile, Okinawa is widely known as a hotspot in archaeology and a lot of ancient remains and digs have been excavated for recent years. Sakitari Cave, where world' s oldest fishhooks were discovered, is one of the most famous archaeological sites in Okinawa.

In this study, fossil shells of a freshwater snail *Semisulcospira libertina* excavated at Sakitari Cave in Okinawa-jima were investigated. These samples were from two sediment layers dated to 13-16 ka and 23 ka in the cave. We measured stable carbon and oxygen isotope ratios and trace element concentrations at intervals of 1 mm along the growth direction of the snails to reconstruct seasonal temperature variations during the Last Glacial Maximum and the last deglaciation. To estimate paleo-temperature and -oxygen isotope composition of precipitation accurately, we also measured oxygen isotope composition of fluid inclusion water in a stalagmite collected near the archaeological site. Comparing with chemical composition of living *S. libertina* shells collected around the site, estimated annual mean temperature was about 8 °C and 6°C lower at 23 ka and 13-16 ka than at the present. Summer temperature has largely increased from 23 ka to 13-16 ka relative to winter temperature, which is consistent with North Hemisphere insolation changes in summer and winter. Our results indicate that the increase of mean air temperature around Okinawa-jima was larger than that of seawater temperature in the northwestern Pacific Ocean during the last deglaciation. This inconsistency is a significant finding for better understanding of past climate changes associated with the East Asian Monsoon.

Keywords: fossil snail, stalagmite, oxygen isotope composition, paleo-temperature, Okinawa, archaeological cave