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Palaeoenvironmental records in a stalagmite from a limestone cave in the Northwest Pacific subtropical region: proxy indexes using annual layer thickness, fluorescent intensity, and stable isotope ratio

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The Ishigaki Island, with its uplifted coral reefs in the south, is located 270 km east of Taiwan Island and has a subtropical marine climate. The Shirahosaonetabaru Cave Site, one of the largest Palaeolithic human sites in Southeast Asia is located near the southeastern coast of the island. We analysed the annual layers and geochemical data of a stalagmite obtained from the site and correlated the palaeoenvironmental proxies to the meteorological record of the island. The results obtained were as follows: (1) About 600-year annual layers with an average thickness of about 0.4 mm were consecutively counted in the stalagmite. (2) Six growth direction changes were observed along the section of stalagmite. However, no clear correlation could be found between the historical earthquakes encountered by the island and the stalagmite growth. (3) Time-series of relative fluorescent intensities of the annual layers have several minimal intervals corresponding to those of the solar radiation intensities. Biological activities producing fluorescent fulvic acids may be affected by solar radiation. (4) The oxygen isotope ratios suggest relatively lower temperatures between AD 1400 to 1700 followed by increasing temperatures after AD 1830. The variation corresponds to the Little Ice Age and the following warming. (5) The carbon isotope ratios suggest frequent changes in C3 and C4 plants vegetation. After AD 1900, the contribution of C4 plants increased probably due to the change in land use for pasture. (6) Based on a comparison between meteorological observation data and the annual layer characteristics, it was found that annual layer thickness and relative fluorescent intensity have larger values with their larger variances when the variation in yearly outside cave temperature was larger. These facts suggest that the active cave air ventilation during the intervals with highly-fluctuating outside cave temperature may have enhanced the growth rates of stalagmite. (7) The fluorescent intensity in the annual layer before AD 1840 was dominated by the pattern gradually increasing upwards in a layer. The palaeoclimate during the Little Ice Age may have caused such kind of pattern. For the last 100 years, this type has formed when the stalagmite growth rate was high with their wide variances and the outside cave temperature and precipitation largely fluctuated over a year, or when the precipitation was large but its coefficient of variation was low. During these intervals, it is suggested that the growth rate of the stalagmite and the co-precipitated amount of fulvic acids increased after the summer because of high precipitation in the late summer and autumn. Thus, it can be concluded that the precipitation in the late summer and autumn was higher in the Northwest Pacific region during the Little Ice Age.