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The origin of erratic calcite speleothems in the Dangcheomul Cave (lava tube cave), Jeju Island, Korea

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Abstract

Dangcheomul Cave in Jeju Island, Korea, is a lava tube about 110 m long. The cave is located only a few meters below the surface under alkali basalt, and contains numerous and various calcite speleothems such as soda straws, stalactites, stalagmites, columns, cave corals, curtains, flowstones, rimstones, carbonate powders, and shelfstones. Carbonate sand dunes overlying the lava tube are responsible for the formation of calcite speleothems. The sand dunes were formed from the carbonate sediments transported from adjacent shallow seas and beaches, and are composed of mollusks, echinoderms, coralline algae, benthic foraminifers, bryozoans, etc. Oxygen isotopic compositions of some speleothems and cave water indicate that the spelothems have grown mostly by evaporation of cave water. Also, carbon isotopic compositions suggest that the majority of carbon was derived from overlying carbonates with a minor contribution of organic carbon from the overlying soil.

Most speleothems in Dangcheomul Cave do not show typical morphology as can be commonly seen in limestone caves. These erratic forms imply a different mode of speleothem formation. High density of soda straws, stalactites, and columns as well as erratic morphology may also provide the evidence that the plant roots are responsible for their growth.

1. Introduction

Dangcheomul Cave is a lava tube in the volcanic terrane of Jeju Island, Korea (Fig. 1). This cave shows typical lava tube morphology and internal microtopographic features as can be seen in many other lava tubes elsewhere; however, it is a lime-decorated lava tube characterized by well-developed carbonate speleothems. Even though Dangcheomul Cave shows many features of lava tubes, lava tube speleothems such as lava stalactites are relatively rare, except for abundant lava helictites on the ceiling which have the same chemical composition as the surrounding basalt (Woo et al., 2000). The cave was accidentally discovered in 1995 by a local farmer when heavy earth-moving equipment broke through the roof of the cave during plowing. Since then, the cave was restored to original natural condition, and is now again overlain by the sand dunes, which are composed of carbonate sediments. Natural forests and shrub thickets, however, are formed on the lava plains surrounding the area outside the Dangcheomul Cave. The carbonate sand dunes should have been blown by wind from beaches and shallow seas nearby even though the accurate age of the dune formation is not known at present (Woo et al., 2000). The preliminary result based on the U–Th dating of the column in Dangcheolmul Cave suggests that the formation of carbonate sand dunes is likely to be during the Holocene Epoch (Woo et al., 2004). The overlying carbonate sediments show a composition similar to the beach sediments reported around Jeju Island (Ji and Woo, 1995). Because the lava tube was developed only a few meters below the surface, it is evident that calcium and carbonate ions for the formation of carbonate speleothems

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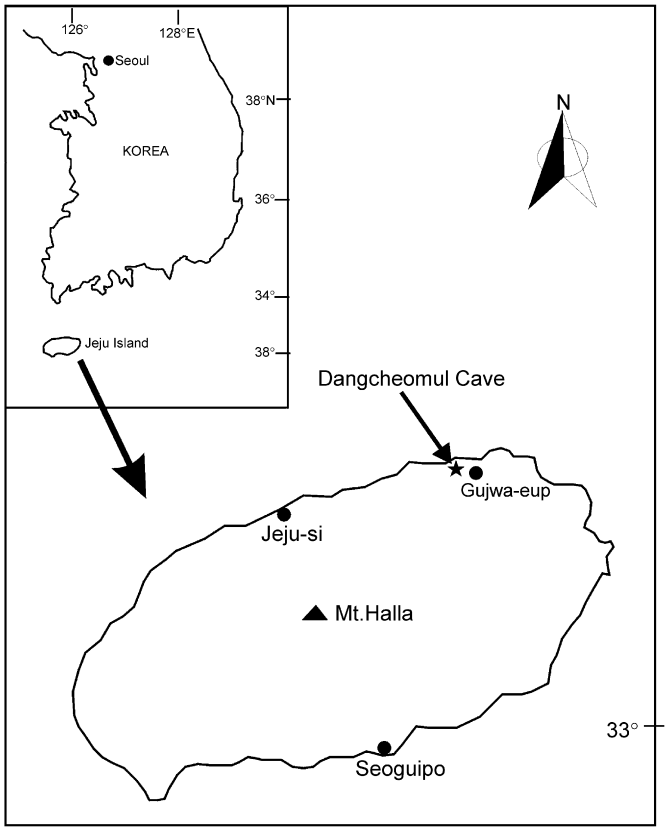

Fig. 1. A map showing the location of the Dangcheomul Cave.

were supplied from overlying carbonate sediments and soils. Numerous calcareous speleothems are growing in the Dangcheomul Cave, and these are soda straws, stalactites, stalagmites, columns, cave corals, curtains, flowstones, rimstones and carbonate powder (moonmilk?). Interestingly enough, many of the stalactites, stalagmites and columns display unusual morphologies that cannot be seen in limestone caves elsewhere. Therefore, the objectives of this paper are to describe the types and distribution of calcareous speleothems in Dangcheomul Cave and to delineate the origin of speleothems based on morphologic, textural, and geochemical data.

2. Geologic setting

Jeju Island, the largest island of Korea (1846 km^2 in area), is located in the Korean Strait about 90 km south of Korean peninsula (Fig. 1). The island is a long ellipse, 73 km east–west and 41 km north–south. It was formed by several stages of volcanic activities during the late Quarternary (about 1 million to a few thousand years BP) by intermittent plume movements, and, as a result, is almost wholly composed of volcanic rocks, mainly trachyte, trachy-andesite, andesite, alkali basalt, and volcanoclastic rocks (Won, 1976). Along with Mt. Halla (a shield volcano), the island includes more than 380 volcanic cones, concentrated in the northeast and southwest part (Yang et al., 1997). Relatively less viscous basaltic lava flows intermittently produced more than 120 lava tubes in the island (Son, 2003).

The lava flows, which are about 0.1–0.4 million years old, are widely distributed along the Jeju coast. Among them, the lava flow field that extends toward the northeast and/or north produced the Geomunoreum Lava Tube System that was formed by several lava flows from the Geomunoreum Crater (Hwang et al., 2005). Several lava tube caves were developed along the paths: Bukoreum, Daerim, Mangjang, Gimnyeong, Yongchon and Dangcheomul. Recent radiometric dating of the basaltic lava in Dangcheomul Cave shows that the cave was formed about 0.15 million years BP (Hwang et al., 2005). Dangcheomul Cave is ca. 110 m long (Fig. 2), and the tube has dimensions of 5.5–18.4 m in width and 0.3–2.7 m in height. The thickness of basalt between the top of the cave and the surface is about 1–4.8 m. The cave is more or less horizontal and shows polygonal columnar jointing in the ceiling. Lava flow structures such as ropy lava, flowlines, gutter and levee are preserved on the floor and wall of the cave.

3. Methods

Cave air temperature, humidity and the partial pressure of carbon dioxide as well as the pH and temperature of cave water were measured from six sites (one site from the outside and five sites within the cave) three times from November 13, 1999 to August 14, 2002 (Table 1; Fig. 2).

Three samples of carbonate sediments from carbonate dune sands above the lava tube cave and one sample from an adjacent carbonate beach were collected to examine the constituents of carbonate grains. The sampled sediments were impregnated with epoxy resin and thin sectioned. Three hundred points were counted from each thin section using a polarizing microscope. Several speleothems were carefully sampled (mostly from the broken specimens) and stained with Feigl's solution to identify aragonite mineralogy (Friedman, 1959). The mineralogy of carbonate powders was determined with an X-ray diffractometer (Bruker D5005).

Cave water and adjacent stream water were collected for stable isotopic and elemental analyses. Surface dwelling plants living on the surface were collected for carbon isotopic analysis. Stable isotopic compositions of oxygen and carbon of carbonate speleothems were measured. All the stable isotope analyses were conducted using stable isotope mass spectrometer (VG PRISM II) from the Korea Basic Science Research Institute. Analytical error range is $\pm 0.2‰$, and all the data in this paper are reported relative to PDB standard except for the water data (vs. SMOW). Trace elements were measured using ICP Emission Spectrophotometer (PQ3 ICPS-1000111) from the Korea Basic Science Research Institute.

4. Cave environment

The environmental conditions of the Dangcheomul Cave have been monitored three times from November 1999 to