The Geological Investigation of the Limestone Caves in South Korea

Kyung Sik Woo, Don Won Choi, and Ryeon Kim
Cave Research Institute of Korea, Kangwon National University,
Chuncheon, Kangwondo, 200-701, Korea

Abstract

The limestone caves in South Korea have been mostly developed within the Cambro-Ordovician carbonate rocks (the Joseon Supergroup), and there appears to be more than 1,000 caves in South Korea. The limestone caves in South Korea are distributed throughout the peninsula, however, most of them are concentrated in the eastern-central part of the peninsula.

Most of the caves have formed by the dissolution of groundwater along joints and bedding planes, and the strike and dip directions of the joints mostly dominate the development of the caves. So far known, the longest cave in South Korea is a Hwanseon Cave, which is about 10 km long. The deepest cave is the Yumundong Cave, which is ca 200 m deep.

The limestone caves in South Korea include a variety of speleothems such as soda straw, stalactite, stalagmite, column, curtain (and bacon sheet), cave coral, helictite (and heligmite), moonmilk, cave shield, cave bubble, cave raft, rimstone, shelfstone, cave pisolite, etc.. All the speleothems are composed of calcite or aragonite, or both. However, aragonite, calcite, gypsum, halite, hydromagnesite, huntite, and dolomite were reported within moonmilk. Textural examination reveals that the speleothems show a variety of microstructures. These are; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous bladed texture, 4) Normally oriented, isopachous columnar texture, 5) Spherulitic fibrous texture, 6) Spherulitic columnar texture, 7) Equant texture, 8) Basket-weave texture, 9) Reel-like texture, and 10) Feathery texture. The difference in texture appears to result from the rate of crystal growth and the saturation state of fluids with respect to carbonate minerals (aragonite and calcite).

The speleothems, composed of aragonite, tend to show higher Sr compositions than calcitic ones, whereas Mg contents in aragonitic speleothems are lower. All the speleothems from different caves show distinctive Sr and Mg compositions, indication that the local supply of trace elements influenced on the trace element contents of the speleothems.

The oxygen isotopic compositions range from –9.4 to –4.0 per mil (vs. PDB). Considering the oxygen isotopic compositions of freshwater, the data suggest that the most of the speleothems formed in oxygen isotopic equilibrium except for some enriched aragonitic ones. The carbon isotopic values are highly variable from –10 to –5 per mil (vs. PDB), and these values are between the carbon isotopic compositions of the organic matter in overlying soil and the surrounding limestone. Using the simple mass balance equations, the influence by two end members is calculated.

Introduction

The geological research on limestone caves and the associated speleothems in South Korea has been carried out past 15 years. Recently, as the local government increased the interest in developing natural caves into show-caves, compiled scientific reports on limestone caves and lava tubes have been published (WOO *et al*., 1995; WOO *et al*., 1999; WOO *et al*., 2001; Woo *et al*., 2001). Among many areas of cave research, especially the mineralogy, texture, and chemical composition of speleothems and the origin of speleothems have been one of the main interest for the Korean cave geologists.

More than one thousand limestone caves are known in Korea, and most of them are concentrated in the eastern-central part of the Korean peninsula (Fig. 1), where the Paleozoic carbonate rocks are exposed. Also, lave tubes are abundant in the Jeju Island, which is a volcanic island and is located about 200 km south of the peninsula. Recently, WOO *et al*. (2000) reported the calcareous speleothems in the Dancheomul Cave (lava tube) in Jeju Island.

This paper deals with the general distribution and the genesis of the limestone caves in South Korea, and the recent result on the genesis of speleothems using textural, stable isotopic, and elemental data.

Geology of Carbonate Rocks

Most of the carbonate rocks in Korea are lower Paleozoic (Cambrian to Ordovician) in age, which is stratigraphically named as “the Joseon Supergroup”. Except for the few locations, most of the limestone contain fossils such as trilobite, echinoderm, brachiopod, gastropod, etc., which indicate shallow marine environments. Also, non-skeletal components such as ooids and oncoids support this interpretation. Numerous sedimentary structures were reported; stromatolite, ripple mark, mud crack, bioturbation, microbial lamination, and birds’ eye structure. Some limestone formations contain argillaceous material (i.e., clays), which hindered the development of the natural caves.

Characteristics of the Genesis of the Limestone Caves

The limestone caves in Korea show horizonal, vertical, and/or combined morphology, depending upon the strike and dip direction of the bedding planes and joints in carbonate rocks. Since the Korean peninsula is located along the Pacific margin, and the Sino-Korean plate collided with Asian continent, tectonic stress resulted in folding and folding of the carbonate rocks, which produced numerous directions of the joints and bedding planes in carbonate rocks. Therefore, most of the limestone caves in Korea have been developed along the joints and bedding planes. Both vadose and phreatic types of passages are present.

Mineralogy and Texture of Speleothems

Calcite and aragonite are dominant minerals comprising the speleothems in Korea. A single kind of speleothems can be composed of one mineral, or both minerals, probably depending upon the Mg/Ca

ratio and/or saturation state with respect to carbonate minerals of the fluid from which the carbonate minerals precipitated. The higher state of saturation or the higher Mg/Ca ratio leads to aragonite precipitation. Based on the examination of the mineralogy of the speleothems in the several limestone caves, curtain (also bacon sheet), fried-egg stalagmite, cave shield, and rimstone are always composed of calcite whereas cave flower is always composed of aragonite. However, cave coral, stalactite, stalagmite, and flowstone are composed of calcite and/or aragonite. In some caves, moonmilk has been reported (WOO *et al*., 1999), and are composed of calcite, aragonite, dolomite, gypsum, huntite, and hydromagnesite. It is notable that the aragonite crystals show the shape of laths and the calcite crystals are anhedral in shape. Also, the hyrdomagnesite minerals show typical monoclinic plates.

Textural examination reveals that the speleothems show a variety of microstructures. Aragonitic textures are composed of; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous columnar texture, 4) Spherulitic fibrous texture, and 5) Spherulitic columnar texture. Calicitic texture shows; 1) Normally oriented, isopachous fibrous texture, 2) Randomly oriented, fibrous texture, 3) Normally oriented, isopachous bladed texture, 4) Normally oriented, isopachous columnar texture, 5) Spherulitic fibrous texture, 6) Spherulitic columnar texture, 7) Equant texture, 8) Basket-weave texture, 9) Reel-like texture, and 10) Feathery texture. The difference in texture appears to result from the rate of crystal growth and the saturation state of fluids with respect to carbonate minerals (aragonite and calcite).

The evolution of one type of speleothems into the other is very common in the limestone cave, soda straw into stalactite, stalactite or stalagmite into cave coral, etc.. This results from the change in rate of water supply (WOO and WON, 1989).

Stable Isotopic and Elemental Results

The oxygen isotopic compositions range from –9.4 to –4.0 per mil (vs. PDB). Considering the oxygen isotopic compositions of freshwater (-10.7 to 9.3 per mil vs. SMOW), the data suggest that most of the speleothems formed in oxygen isotopic equilibrium except for some enriched aragonitic ones (CHOI, 2000). The carbon isotopic values are highly variable from –10 to –5 per mil (vs. PDB), and these values are between the carbon isotopic compositions of the organic matter in overlying soil and the surrounding limestone. 17 to 36% of the carbon in the speleothems was supplied from soil-derived carbon dioxide and 64 to 83% from the surrounding carbonate rocks.

The speleothems, composed of aragonite, tend to show higher Sr compositions than calcitic ones. Aragonitic speleothems show low Mg contents, whereas calcitic ones contain various Mg contents. All the speleothems from different caves show distinctive Sr and Mg compositions, indication that the local supply of trace elements influenced on the trace element contents of the speleothems.

Calcitization

The cave coral, stalactite, and flowstone in some limestone caves of Korea, which were originally composed of aragonite, were calcitized. The neomorphic calcite crystals contain reilic of the original aragonite crystals and growth laminae. The presence of these relics in neomorphic calcite as well as the similar Sr and Mg contents to the original aragonite suggests that the most the calcitization processes took place in a semi-closed diagenetic system via thin-film alteration front.

Summary

1. Limestone caves and lava tubes are present in Korea, and most limestone caves in Korea have been developed within the lower Paleozoic carbonate rocks.
2. Due to the tectonic movement of the Korean peninsula, the limestone caves in Korea have been formed along the strike and dip directions of the joints and bedding planes in carbonate rocks.
3. Most speleothems are composed of aragonite and/or calcite.
4. The calcitic speleothems show 10 types of microstructure, and and the aragonitic speleothems show 5 types.
5. Oxygen isotopes in aragonitic speleothems tend to be more enriched than calcitic ones, indicating that the aragonitic speleothems have been formed due to evaporation rather than degassing of carbon dioxide.
6. Some originally aragonitic speleothems have been replaced by calcite, due to the change of the chemical composition of cave water.

References

Choi, D. W. 2000. Textural and elemental investigations of speleothems in limestone caves, Kangwon-do and Chungcheongbuk-do, Korea, a M.S. Thesis, Kangwon National University, 128p.

Woo, K. S. and Won, C. K. 1989. Original mineralogy and carbonate diagenesis of speleothems in Kwanum and Hwansun Cavern, Kangweondo, Korea: Preliminary results, Journal of the Geological Society of Korea, 25, 90-97.

Woo et al., 1995. A scientific report of the Yongyeon Cave, Kangwondo, 135p.

Woo et al., 1999. A scientific report of the Okgye, Dongdae, and Namdae Caves, Kangwondo, 269p.

Woo, K. S., Choi, D. W., Kim, R. and Kim, J. K. 2000. The origin of the speleothems in Dangcheomul Cave, Jeju Island, Korea, Journal of the Geological Society of Korea, 36, 411-434.

Won et al., 2001. A scientific report of the Kwanuem Cave, Kangwondo, 194p.

Woo et al., 2000. A scientific report of the Chodang Cave, Kangwondo, 202p.