American Mineralogist, Volume 60, pages 1118–1121, 1975

MINERALOGICAL NOTES

Fiber-containing and Crystal-lined Basaltic Vesicles: Possible Lunar Analogs[1]

JOHN J. NAUGHTON
Chemistry Department, and Hawaii Institute of Geophysics, University of Hawaii, Honolulu, Hawaii 96822

Abstract

Unusual whisker-like siliceous features occur within the gas-formed vesicles that are conspicuous in many of the basaltic stalactites in lava tubes. The vesicle linings are composed of well-formed crystals in most cases, and crystal-lined vugs branch off from the vesicles. The very small, nodular fibers are about 0.5 μ in diameter and up to about 2 mm long. Another class of crystalline feldspar whiskers of larger diameter also are present. The mechanism of formation is uncertain, but the finer fibers may possibly be fibrils of mesostasis drawn out by the parting of crystals during vesicle expansion. The crystal-lined, whisker-containing vesicles resemble those in lunar basalts, and, at least in some cases, may have been produced by similar processes.

Introduction

The morphological features of the interiors of the gas-formed vesicles that are conspicuous in basaltic stalactites found in lava tubes may involve the same mechanism of formation as similar features noted in the linings of vugs and vesicles of lunar basalts. Jaggar (1931) was probably the first to describe the *in situ* behavior of stalactites at high temperatures in lava tubes, and to suggest a mechanism of formation from the gas-melted glaze on the roofs of the tubes. Jaggar also noted the characteristic appearances and forms of the stalactites, and the crystallinity of the lining of the vesicles within them. Recently, Peterson and Swanson (1974) vividly described such stalactites from the tube system of the 1970–71 Kilauea eruption on the east rift zone vent at Mauna Ulu. They suggest stalactite formation both by dripping of lava splashed from the flowing stream within the lava tube, and, for the more slender "worm stalactites," by the slow dripping of the viscous glaze from the lava tube roof.

Procedures

Stalactites were obtained from the collections of the Department of Geology and Geophysics, University of Hawaii, and of the Hawaiian Volcano Observatory, U. S. Geological Survey. Most samples are from lava tubes formed during the extensive 1919 eruptions in Kilauea Caldera.

To avoid contamination, new vesicles were opened for study with reflecting optical microscopes at magnifications from 10× to 200×. Crystals and fibers were also broken and removed from within the vesicles and studied with transmission optical microscopy. However, the most productive examinations were those using the scanning electron microscope (SEM) on graphite-coated samples. Preliminary attempts to analyze individual fibers and crystals using an energy dispersive X-ray attachment of the SEM were only of qualitative value due to the limitations of the instrumentation available.

Results and Discussion

SEM photographs of the vesicle linings (Fig. 1) reveal the distinctive crystallinity characteristic of most vesicle linings. Individual minerals seem to be predominant in certain wall regions; feldspar is especially prominent in some areas, augite in others. Neither the extent nor the reason for this sequestering of minerals in certain areas has been explored as yet. Remnants of the mesostasis are held by capillary action between many closely adjacent crystals (Fig. 1A, arrow), and in this instance may be an early stage of fiber formation. In some cases the crystal surfaces follow the interior spherical form of the vesicle, and are often broken or parted to reveal crystal-lined vugs that penetrate beyond the boundary of the vesicle walls.

The smaller fiber-like structures are present in a variety of forms. The individual fibers vary in diameter and may best be described as nodular (Figs.

[1] Hawaii Institute of Geophysics Contribution No. 704.

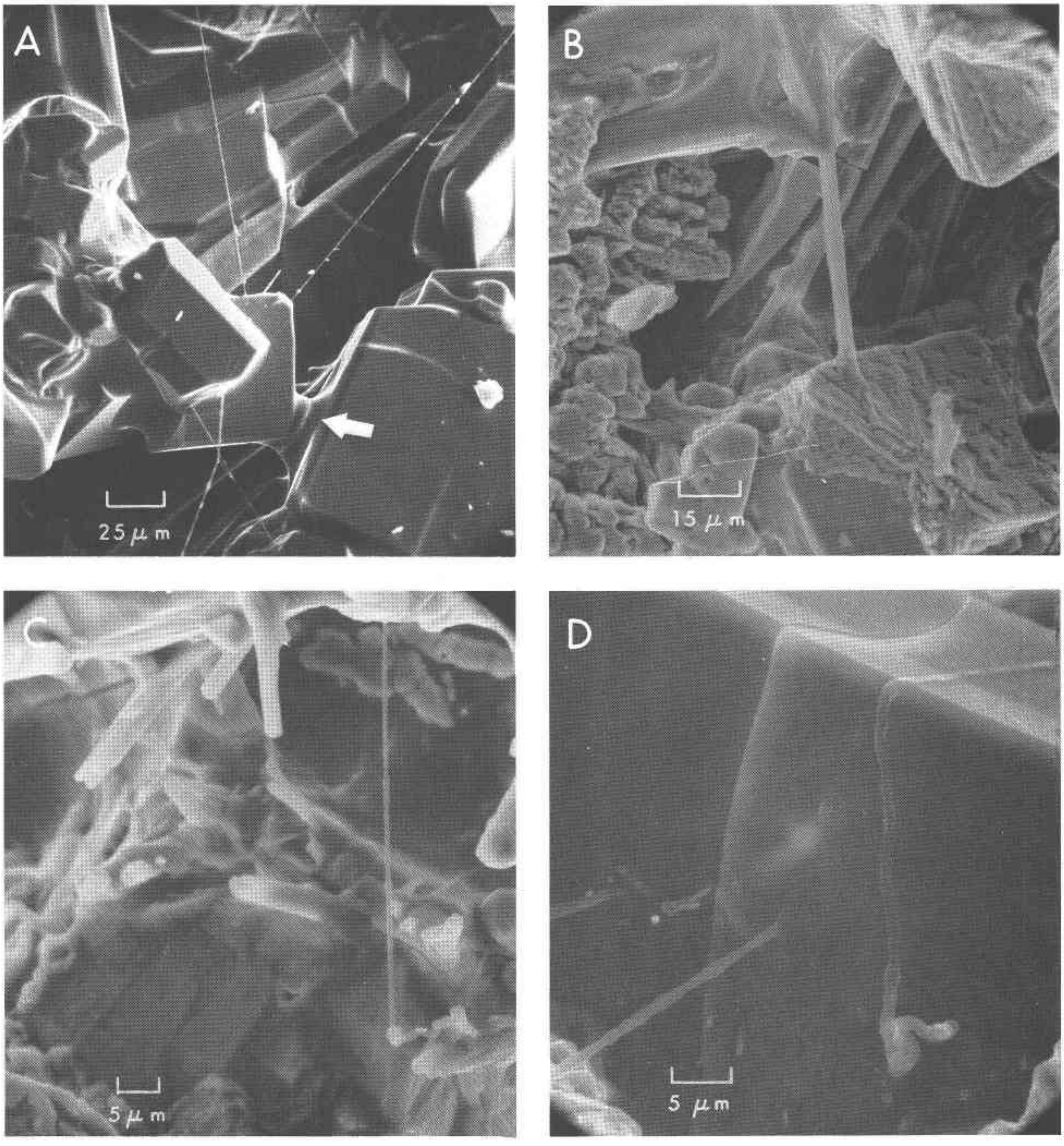

FIG 1. SEM photographs of characteristic features in crystalline linings of vesicles in basaltic stalactites from lava tubes. See text for discussion of details.

1C and 1D), and fibers in a given region may represent several generations of growth or formation. A class of larger fibers with crystal-faced surfaces and terminations also are evident (Fig. 1C), and have been identified microscopically as feldspars (An_{50-70}). Some of the finer fibers have droplets of a solidified phase adhering to them, as if after formation they had been exposed to a liquid with a lower melting point (Fig. 1A). Some fibers are sharply terminated; possibly broken in handling (Figs. 1A and 1D). Others terminate in twisted, worm-like growths (Figs. 1C and 1D), similar to the growths observed on some of the stalactites in which the vesicles are found. Some fibers may have been broken after formation and have collapsed, as can be seen in Figure 1D, in which a fiber lies limply across a crystal from which other fibrils protrude. The worm-like twists with which some fibers terminate are difficult to explain. In stalactites, this type of twisted formation is usually attributed to the buffeting that the stalactites receive at high temperatures from the turbulent gases in the lava tubes when they are in a softened condition and behave "like macaroni before it has dried" (Jaggar, 1931). It is difficult to understand how a similar condition could exist within the vesicles, or how only the fibril ends could be distorted by such action.

Analyses, using the electron beam of the SEM with energy dispersion of the X-rays generated, showed the presence of Si, Al, Fe, Ti, Ca, Na, and K in the smaller class of fibers. Only the relative abundances could be determined; these varied from fiber to fiber and even with position on the fiber. This variation suggests the fiber to be a residuum consisting of a very fine-grained heterogeneous mixture of minerals, probably supported in a glassy matrix. The nodular appearance of the fibers may be due to variations in the size of the included microlites; and the glassy character could be imputed to them from their having been "drawn out" to the fiber form while in the extended softening temperature range characteristic of glasses.

From the appearance of both fibers and crystals, one can postulate that they may have been formed by the growth of gas vesicles within the stalactites under conditions in which the gas pressure need only overcome the surface tension effects of the semi-fluid matrix of the thin-walled stalactites. Pressure due to the "head" of the lava, as occurs in more massive lava bodies, would not be an important factor in confining the growth of such bubbles. With but few crystals in the lava matrix, the crystal surfaces would conform to the minimum energy condition of the spherical bubbles; but with increased crystal growth and formation of a rigid crystal mixture, crystals would be left penetrating into the vesicle, and the gas pressure would form pathways into the body of the lava, resulting in the formation of vugs. Usually, vesicle walls are glassy or microcrystalline, but somewhat this same type of vug formation and well-defined crystal lining has been noted in vesicles formed in coarse-grained lava flows (the 1881 flow from Mauna Loa, for example), but with little penetration of the crystals within the body of the vesicle. The fibers could be formed from the mesostasis that is drawn out as crystals become parted during the growth of the vesicle. It should be emphasized that this explanation is preliminary and is probably an over-simplification, and that further studies of these interesting bodies is certainly needed.

The well-formed crystallinity of the linings and the existence of fibers within the vesicles resemble features noted in the vesicles and vugs of the lunar basalts from the Apollo missions. The importance of the study of those vesicles and some of their unique features was emphasized by Schmitt *et al* (1970). Others have described and studied the crystallinity of vesicle and vug linings (Jedwab, 1971; Skinner and Winchell, 1972), and the writer has been impressed by this feature in work with the vesicular Apollo 15 basalt, 15556. Fibers have also been described as intruding into the vugs and vesicles of lunar basalts (Skinner and Winchell, 1972), and on the surfaces of lunar breccias (Carter, 1973). The general conclusion has been that fibers or "whiskers" in lunar vesicles are the product of growth from a vapor phase, or through a vapor-liquid-solid (VLS) sequence (Carter, 1973). In light of similar features in terrestrial samples, further studies on lunar basaltic vesicles are needed, with perhaps a re-examination of other possible processes that might be involved in their formation.

Acknowledgments

I wish to thank my colleague G. A. Macdonald for helpful discussions and for supplying some of the stalactite samples. Others were supplied by D. W. Peterson of the Hawaiian Volcano Observatory, U. S. Geological Survey. Also I wish to thank James Gooding for help with microscopic studies, and especially Stanley and Karen Margolis of the Hawaii Institute of Geophysics who did the SEM photography and analyses. Part of the work received support under National Science Foundation Grant GA-39800.

References

CARTER, J. L. (1973) Morphology and chemistry of probable VLS (Vapor-Liquid-Solid)-type of whisker structures and other features on the surface of breccia 15015,36. *Proc. 4th Lunar Sci. Conf., Geochim. Cosmochim. Acta, Suppl. 2,* **1**, 413–421. Pergamon Press.

JAGGAR, T. A. (1931) Lava stalactites, stalagmites, toes and "squeeze-ups." *Volc. Lett. Hawaii Volc. Res. Assoc.* **345**, 1–3.

JEDWAB, J. (1971) Surface morphology of free-growing ilmenites and chromites from vuggy rocks 10072,31 and 12036,2. *Proc. 2nd Lunar Sci. Conf., Geochim. Cosmochim. Acta, Suppl. 4,* **1**, 923–935. MIT Press.

PETERSON, D. W., AND D. A. SWANSON (1974) Observed formation of lava tubes during 1970–71 at Kilauea Volcano, Hawaii. *Stud. Speleol.* **2**, 209–222.

SCHMITT, H. H., G. LOFGREN, G. A. SWANN, AND G. SIMMONS (1970) The Apollo 11 samples: Introduction. *Proc. Apollo 11 Lunar Sci. Conf., Geochim. Cosmochim. Acta, Suppl. 1*, **1**, 1–54. Pergamon Press.

SKINNER, B. J., AND H. WINCHELL (1972) Mineralogical evidence for subsolidus vapor-phase transport of alkalis in lunar basalts. *Proc. 3rd Lunar Sci. Conf., Geochim. Cosmochim. Acta Suppl. 3*, **1**, 243–249. MIT Press.

Manuscript received, April 15, 1975; accepted for publication, June 13, 1975.