CRISTOBALITE IN SOUTHWESTERN YELLOWSTONE PARK

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Introduction

Megascopic cristobalite has been found at several localities in the United States. Rogers[1] has described specimens from three California localities and in his 1922 paper reports that he has obtained specimens from five others. Shannon[2] found cristobalite crystals 0.5 mm. in size in vesicular cavities in basalt at Spokane, Washington. Foshag[3] has described megascopic cristobalite from Obsidian Cliff in Yellowstone Park, and Larsen[4] has reported cristobalite of visible size in southwestern Colorado. In spite of these occurrences, megascopic cristobalite is rare although no longer an oddity. Microscopic cristobalite, on the other hand, is much more widespread. Larsen (*op. cit.*, 682) reports that it is fairly widespread in about one-tenth of the lavas of the San Juan region, but adds that it rarely makes up more than a small fraction of one per cent of any lava.

The purpose of the present paper is to call attention to additional occurrences of cristobalite in Yellowstone Park and to record certain observations bearing on the genesis of the mineral. The cristobalite is not only widespread but relatively abundant.

Occurrences

The writer's attention was first called to the new occurrences of cristobalite by Dr. Francois Corin of the Belgium Geological Survey who reported tiny white pellets in the obsidian along the road about a half mile south of the junction of the Firehole and Gibbon Rivers (Fig. 1). Recently the writer was afforded opportunity to check the identity of the mineral and to determine its relative abundance in this immediate region.

[1] Rogers, A. F., The occurrence of cristobalite in California: *Am. Jour. Sci.*, (4), ***XLV***, 222–226 (1918).

Rogers, A. F., A new occurrence of cristobalite in California: *Jour. Geol.*, **30**, 211–216 (1922).

[2] Shannon, Earl V., On siderite and associated minerals from the Columbia River basalt at Spokane, Washington: *Proc. U. S. Nat. Mus.*, **62**, Art. 12, 1–17, with pls. 1–3 (1923).

[3] Foshag, W. F., The minerals of Obsidian Cliff, Yellowstone National Park, and their origin: *Proc. U. S. Nat. Mus.*, **68**, Art. 17, 1–18, with pls. 1–4 (1926).

[4] Larsen, E. S., and others, Petrologic results of a study of the minerals from the Tertiary volcanic rocks of the San Juan region, Colorado: *Am. Mineral.*, **21**, 679–701, Section 2, The silica minerals, 681–694 (1936).

The cristobalite pellets at the locality examined by Dr. Corin average less than 0.2 mm. in size. Since their discovery, the writer has found other exposures in which the pellets average slightly less than a millimeter in diameter with some slightly larger. Most of the megascopic cristobalite pellets described from other American localities are also less than a millimeter in diameter. A recent text[5] mentions cristobalite "eggs"

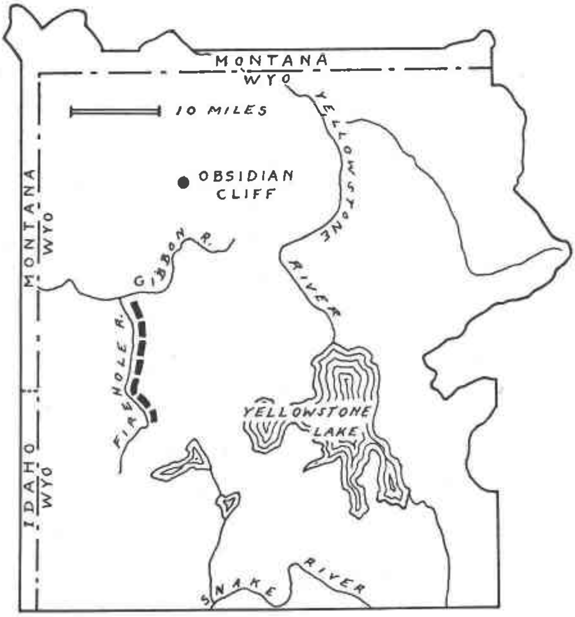

FIG. 1. Yellowstone National Park. Cristobalite has been described from Obsidian Cliff. The new localities are indicated by the heavy broken line.

two inches in diameter from near Little Lake, California. In the specimens from this locality in the collection at Columbia University, the cristobalite occurs in lithophysae up to two inches in diameter but the pellets themselves are only about a millimeter in size.

The cristobalite herein described occurs in the rhyolite lava exposed along the road for 14 miles south of the junction of the Firehole and Gibbon Rivers. Some of the exposures contain visible cristobalite in appreciable quantity; others have so little that careful and intensive search is required to find it; and a few show none at all. No attempt was made to trace the cristobalite-bearing rock away from the road.

[5] Quartz Family Minerals, Dake, H. C., Fleener, F. L., and Wilson, B. H., McGraw-Hill Book Co., New York, **1938**, p. 85.

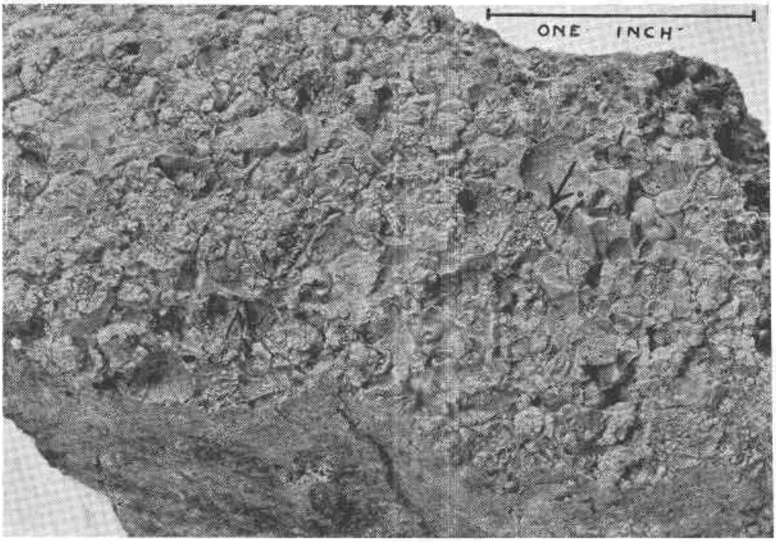

FIG. 2. Specimen showing megascopic cristobalite. Arrow indicates a cluster of the pellets. From 0.6 mile south of junction of Firehole and Gibbon Rivers. (Photograph by James Bush.)

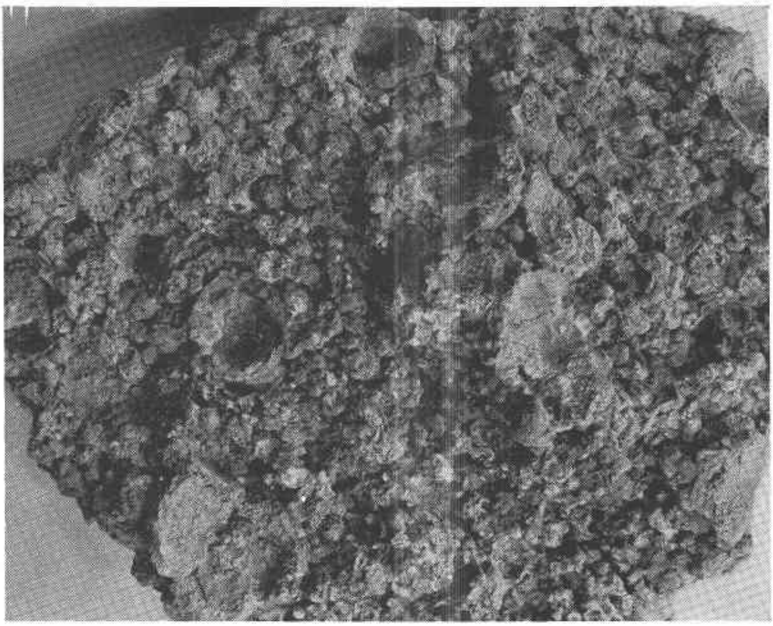

FIG. 3. Specimen showing an agglomeration of spherulites and lithophysae with almost no intervening glass. Cristobalite pellets are discernible in some of the lithophysae. (Photograph by James Bush.)

Many of the outcrops are of a perlitic, flow-banded vitrophyre. In many exposures the rock is strongly folded and brecciated. The cause of the folding and brecciation was not investigated, but it is interesting to note that the cristobalite is largely confined to the disturbed rocks. The vitrophyre contains numerous spherulites and lithophysae. The latter bodies, though generally of small size, often exceed an inch in diameter. The glass itself is often mottled due to differential alteration. In some specimens only the kernels of the perlitic granules are black; the intervening glass is gray. The mottled varieties are the most porous and inasmuch as the cristobalite content varies with the porosity, the black, fresher-appearing glass shows little or no cristobalite, while the mottled varieties contain much. The porosity is due to the presence of lithophysae and of highly irregular, sometimes long drawn out cavities which often ramify and branch through the rock in so thick a network that the rock appears almost sponge-like. Many of the long irregular cavities clearly represent strings of lithophysae joined by destruction of their communal walls. Lithophysae in different flow bands are often connected across the grain of the flowage. However, many irregular cavities bear no resemblance to individual or compound lithophysae. These will be discussed later.

The cristobalite occurs as tiny spheres on the walls of lithophysae and other cavities (Figs. 2 and 3). The pellets are milky white and vary from translucent to opaque. Some are covered by tiny, tabular prisms of tridymite. In the exposures 2.6 miles south of Madison junction many of the lithophysae are more than an inch in diameter and the largest cristobalite pellets, about a millimeter in diameter, are to be found here. Some of the specimens collected show only an agglomeration of spherulites and lithophysae; there is almost no intervening glass. Except for the lithophysae, then, the pore spaces in these specimens are highly irregular.

The remaining exposures show stony rhyolite with very little pore space; the rock is massive, with neither layering nor brecciation, and, in common with the undisturbed facies of the glassy rock, contains little cristobalite. Where the stony rhyolite is altered by hydrothermal activity, cristobalite is frequently found in the more affected portions. In some exposures hydrothermal alteration has been localized along joint planes and cristobalite is found only along these planes.

Identification of Minerals

The cristobalite and associated minerals were first examined in thin section (Fig. 4). The cristobalite occurs in subround pellets, individually or in groups. Its refractive indices with respect to balsam, its birefringence, and its peculiar fracture check with the descriptions in standard works of reference. The cristobalite is associated with tabular prisms of tridymite, and with encrustations of chalcedony.

The identity of the silica minerals was then checked by immersion in index liquids. The indices of the cristobalite lie between 1.481 and 1.489; those of the tridymite lie below 1.481. These observations agree with published data.

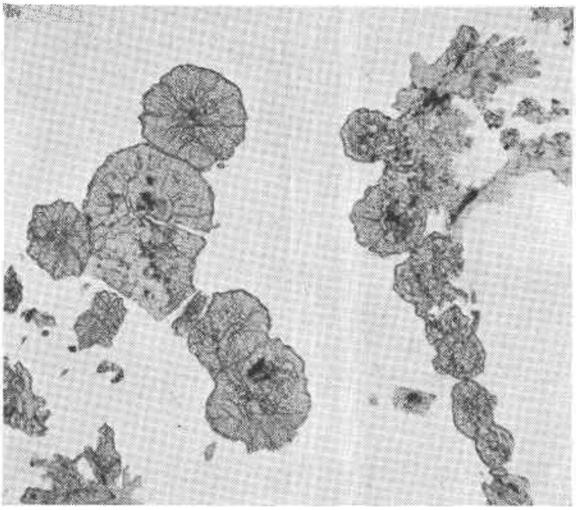

FIG. 4. Cristobalite pellets in rhyolitic vitrophyre. Note characteristic wavy fracture. The largest pellet is about a millimeter in diameter. (Photograph by E. N. Cameron.)

A quantity of the cristobalite was then separated from crushed material for x-ray examination.[6] The x-ray pattern indicates a mixture of cristobalite and chalcedony.

ORIGIN OF THE CRISTOBALITE

Foshag (*op. cit.*, 13–17), in his paper on the cristobalite of Obsidian Cliff, attributes the formation of the cristobalite at that locality to a reaction between aqueous solutions trapped within the lithophysae and the glassy wall rock, rather than to introduction of material by invading solutions. As evidence against introduction of the silica minerals by aqueous solution, he points out that the glass is fresh to the very walls

[6] The separation was made under a binocular-microscope by means of an appliance described by the writer some years ago. (A simple appliance for the manipulation of individual detrital grains of minute size, *Sed. Petrol.*, **2**, 160–161 (1932).) Its ease of manipulation recommends the instrument for use in the handling of tiny mineral or rock particles.

of the lithophysae in spite of its susceptibility to alteration by hot aqueous solutions. The freshness of the glass is all the more remarkable in Foshag's opinion because of the great volume of solvent that would be required to introduce the relatively insoluble cristobalite and associated minerals. He believes introduction by gaseous solutions is also improbable because of the lack of evidence of abundant supplies of fluorine, chlorine, and other mineralizers necessary to transport the molecules of the minerals of the lithophysae in the form of volatile compounds. Analyses published by Foshag show a marked similarity in composition among the lithophysae, spherulites, and the obsidian. This supports his hypothesis that the minerals of the lithophysae of Obsidian Cliff were formed from materials which originated within the lithophysae themselves by reaction between trapped aqueous solutions and the glass.

In the writer's opinion much of the cristobalite of the lithophysae in southwestern Yellowstone may have formed in a similar fashion. The presence of the greatest volume and the largest pellets of cristobalite in the largest lithophysae may be evidence of such an origin. There are reasons for believing, however, that some of the cristobalite outside the lithophysae was formed by invading solutions. The local, intense hydrothermal alteration of the rocks suggests penetration by solutions. In many of the specimens the glass is so altered that only the innermost kernels of the perlitic granules retain their original black color; the intervening glass is gray. In other specimens, to be described shortly, the glass has been entirely removed.

The most suggestive line of evidence favoring invading solutions is that in some exposures of relatively fresh rock, cristobalite was found only along joint cracks where the rock was appreciably altered, as though the fractures acted as passages for siliceous solutions. In other specimens occasional tiny seams of cristobalite are found, but since these lie parallel to the flowage, the possibility remains that they were formed by reaction between the glass and solutions which dissolved their way along certain flow planes from nearby lithophysae. Many of the long drawn out cavities may represent a similar type of solution along flow planes by solutions originally trapped in lithophysae. Others, however, may well have been formed by invading fluids following flow layers.

One of the specimens (Fig. 3) shows a surface on which practically no glass is visible. It displays a mixture of spherulites and lithophysae separated by irregular spaces. That these spaces were originally occupied by glass may be inferred from the presence of remnants of intervening glass. In view of their intimate association it seems reasonable to suppose that the alteration of the rock and the removal of the glass was accomplished by the same agencies. The rhyolite over wide areas in Yellowstone is being altered at the present time by rising aqueous and gaseous solutions. In the exposures examined, cristobalite is most common where the rock is altered. Hence it is probable that the leaching of the glass and the precipitation of at least part of the cristobalite was accomplished by invading solutions. It is quite possible that cristobalite is being formed at the present time.

The high porosity and the large percentage of cristobalite in some of the specimens might also be considered evidence of invading solutions. It is difficult to imagine so great a concentration of aqueous solution during the solidification of the rhyolite as to fill all the pore spaces in these highly porous specimens, and to furnish all the silica of the contained cristobalite. It is simpler to suppose that much of the porosity is due to the solvent action of invading solutions, and that part at least of the cristobalite was formed by interaction between invading solutions and the glass. Although much of the silica was undoubtedly liberated from the glass by the invading solutions, some of it may have been introduced by these solutions.

Summary

New occurrences of cristobalite are described from southwestern Yellowstone Park. Some of the cristobalite was probably formed by reaction between solutions trapped in lithophysae and the cavity wall rock, as proposed by Foshag for the cristobalite of Obsidian Cliff. The remainder may have been formed by reaction between invading solutions and the glass. Inasmuch as aqueous and gaseous solutions are permeating the rocks over wide areas in Yellowstone Park at the present time, cristobalite may even now be in process of formation.

Acknowledgements

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