HYDROTHERMAL DEPOSITS IN THE SPECIMEN MOUNTAIN VOLCANICS, ROCKY MOUNTAIN NATIONAL PARK, COLORADO

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ABSTRACT

Specimen Mountain, in Rocky Mountain National Park, Colorado, is a denuded Tertiary explosive volcano. Thrust faults displace its core and flanking pyroclastics and flows and have provided channelways for hydrothermal solutions rising from depth. Jasper and opal deposited from these solutions have replaced pitchstone flows adjacent to the faults. Locally the jasper forms geodes, partly or completely filled with agate, onyx, opal, calcite, and minor amounts of allophane and chloropal. Sufficient time elapsed between the periods of eruptive volcanism and hydrothermal mineralization to permit an intervening period of extensive thrust faulting.

CONTENTS

LOCATION

Specimen Mountain (elevation 12,482 feet) is a prominent landmark standing above the continental divide at the crest of the Front Range of Colorado (Fig. 1). It lies just north of Poudre Lake at Milner Pass in the northwestern corner of Rocky Mountain National Park. Streams on the south side drain into the headwaters of the Cache la Poudre River; streams on the north side enter the headwaters of the Colorado River.

During the summer months Specimen Mountain is easily reached by excellent auto roads from either Estes Park or Grand Lake. Horse and foot trails lead from Poudre Lake into the heart of the area described in this paper.

FIELD WORK AND ACKNOWLEDGMENTS

The writer visited Specimen Mountain on several occasions during the summers of 1934 to 1940, but it was not until the summer of 1940 that an extensive investigation was begun. In September, 1940, working as a collaborator with the National Park Service and aided by funds generously donated by the Research Council of the University of Colorado, a month was spent in the area.

The writer wishes to express his appreciation for the services of Mr. Olwin Woodbury, who spent two weeks in the area as field assistant. Mr. Raymond Gregg of the National Park Service greatly expedited the work by his interest and cooperation; Dr. Carol Wegemann, Mr. David

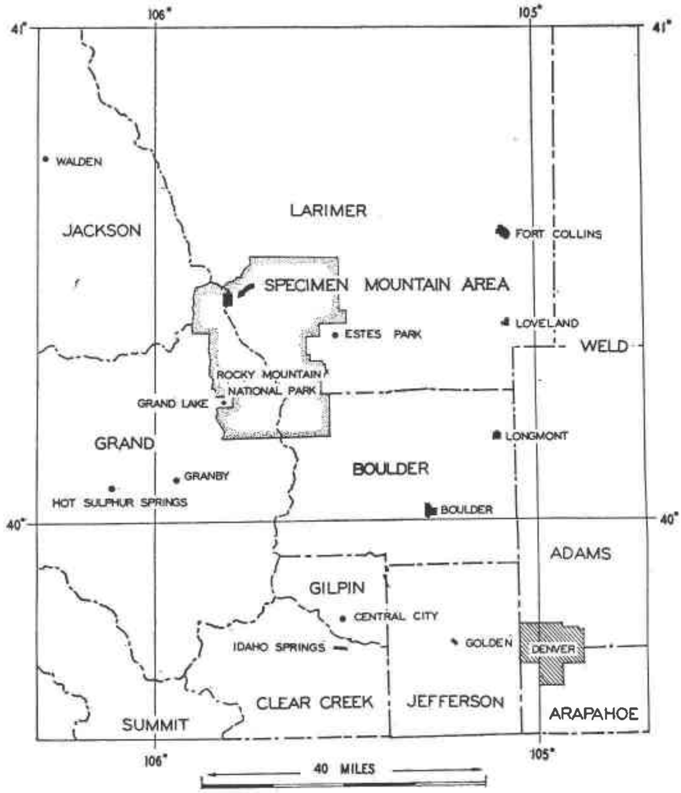

FIG. 1. Outline map of north-central Colorado showing location of Specimen Mountain area.

Canfield and Mr. H. E. Rothrock, all of the National Park Service, facilitated the work by cooperating to the fullest extent. Dr. Wegemann, who spent a day in the field with the writer, offered many helpful suggestions. Dr. W. O. Thompson of the University of Colorado critically read the manuscript.

Geologic Setting

The oldest rocks of the area are the gneisses and schists of the pre-Cambrian Idaho Springs formation, which is composed of highly metamorphosed sediments, intensely folded and injected by sills of pegmatite, aplite and gneissoid granite. These rocks are displaced by extensive faults and shear zones of unknown age.

Specimen Mountain consists essentially of the dissected remnants of a Tertiary explosive volcano which mantled a broad area of maturely dissected pre-Cambrian rocks with a thick covering of pyroclastics and lava flows. Streams and glaciers have effectively exposed the core and

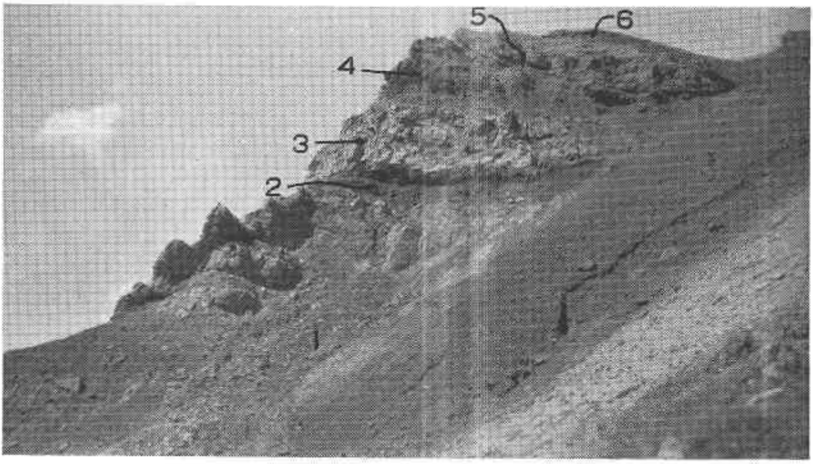

Fig. 2. Cliff exposure of pyroclastics and flows. Southwest side of Specimen Mountain.
1—Ash and breccia with agglomerate layers.
2—Pitchstone containing jasper lenses and geodes.
3—Ash and breccia.
4—Pitchstone containing jasper layers and geodes.
5—Jasper layer partly replacing pitchstone.
6—Ash bed.

flanking ejectamenta of what at one time must have been a very impressive volcanic cone (Fig. 2). Specimen Mountain itself is actually an outlier of an extensive volcanic area which lies to the west and northwest in the Never Summer Range.

The top of Specimen Mountain (Fig. 3) approximately marks the center of the conduit which provided a channelway for the movement of molten lava from depth. In plan the conduit is subcircular and is filled with a porphyritic rock near quartz trachyte in composition. This rock consists largely of phenocrysts of sanidine embedded in a dense to glassy groundmass containing, in addition to sanidine, biotite, amphibole, pyroxene, magnetite, and, locally, abundant tridymite.

The structural history of Specimen Mountain is complex. Field work has disclosed the fact that the cessation of volcanic activity was marked by a period of thrust faulting, which produced a series of thrust slices each bounded above and below by flatly dipping fault zones. These faults, which are exposed best in the bedded pyroclastics on the west side of

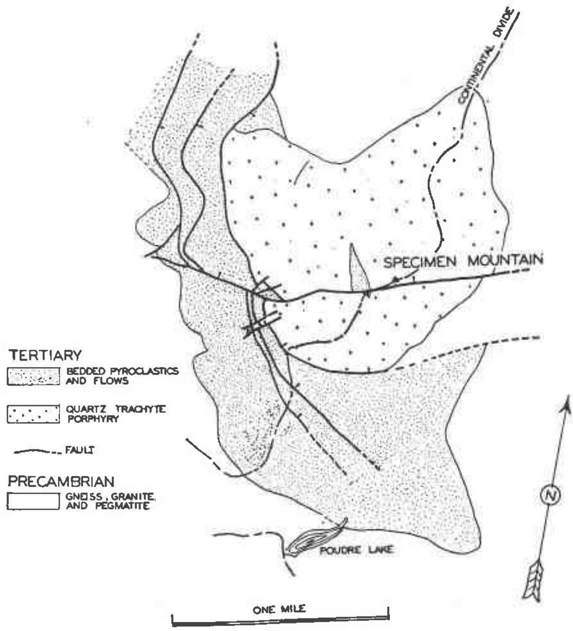

Fig. 3. Outline geologic map, Specimen Mountain area, Colorado. Geology plotted in field on aerial photographs.

Specimen Mountain, in general strike northwest and dip to the northeast at about thirty degrees. The faults provided channelways for the circulation of late mineralizing solutions from which was deposited an interesting assemblage of minerals.

Bedded pyroclastics and flows are not present in the east and north sides of Specimen Mountain, and those that are found on the west and south sides probably are present only by virtue of the fact that they occur in thrust fault blocks and were buried and protected from rapid denudation by a mass of rock greatly thickened by faulting.

The pyroclastics and glassy and porphyritic flows form a thick section ranging from basalt to quartz trachyte in composition. Thick beds of agglomerate, breccia, ash and cinders, and tuff are locally prominent. In general, the lowest and oldest beds or flows, at the bottom of the section, are more mafic than those higher up. The uppermost layers have essentially the same composition as the rock in the core of the volcano. Noteworthy are two layers of pitchstone, each with a thickness averaging about fifteen feet and occurring high in the section. These are quickly chilled lava flows and crop out in the cliffs on the west and southwest sides of Specimen Mountain.

Mineral Deposits

General Statement

The pitchstone layers have been replaced in part by abundant jasper and opal. These minerals are found in small quantity in other rock types, but their concentration in the pitchstone indicates that this rock provided the most favorable environment for deposition. Jasper and opal are abundant also in the faults cutting the pyroclastics. Associated with the jasper and opal are minor amounts of other minerals, including agate, onyx, calcite, allophane, and chloropal (nontronite).

Structural Control

The jasper and opal and accompanying minerals are structurally related to the thrust faults as is indicated in Fig. 4. Mineralizing solutions moving along these faults deposited part of their load in the faults and locally silicified the fault breccia. Silicification is present in most exposures of the faults, but is most prominent where the fault breccia is thickest.

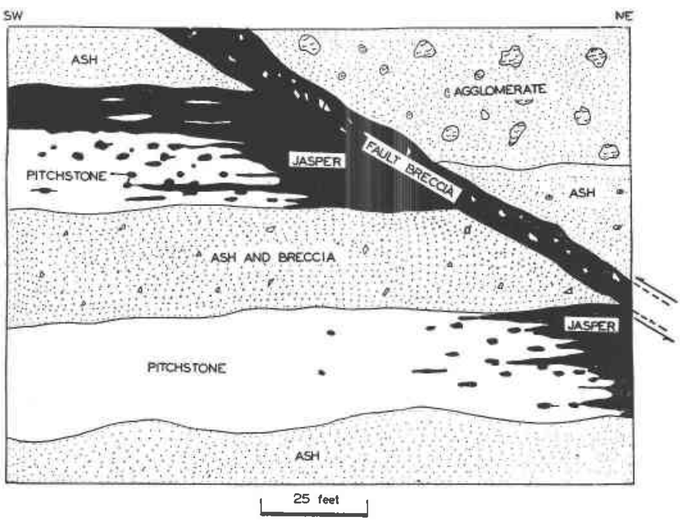

Fig. 4. Idealized cross section showing jasperization of pitchstone flows adjacent to a thrust fault. Southwest side of Specimen Mountain.

The extent to which the rocks adjacent to the faults are replaced probably reflects the permeability of the various layers. Tuff beds, agglomerates, and ash beds, because of the presence of impervious bentonitic alteration products, were unfavorable media for the free circulation of solutions. Likewise, massive, dense flow-rocks in the lower part of the section did not permit entrance of large amounts of solutions. However, the brittle pitchstone beds in the upper part of the section are highly fractured and relatively pervious.

Inspection of Figure 4 shows that the replacement of the pitchstone next to the faults resulted in complete obliteration of all previous structures, except bedding. As the solutions moved away from the faults, the replacing action became less intense and only part of the original rock was replaced. At a distance from the faults the only manifestations of replacement are jasper geodes, or concretions, which are localized by closely spaced, onion-like spherical shrinkage fractures.

Minor fractures in other rock types contain inconspicuous deposits of the minerals found in the pitchstone.

Mineralogy

The *jasper* in the faults and pitchstone flows consists largely of gray-brown to red-brown chalcedony containing disseminated fine-grained hematite and limonite. Contacts between the jasper and pitchstone are billowy. In detail the surfaces of the jasper masses display crowded knotty, approximately hemispherical protuberances ranging from a fraction of an inch to several inches in width. These appear to be layered but are actually massive within. The layered appearance results from the partial preservation of closely spaced flow structures in the replaced pitchstone.

Gray and green *agate*, *onyx*, *opal* and *calcite* partially or completely fill the interiors of hollow concretions, or geodes (Fig. 5). These minerals were deposited after the interiors were etched out because of a change in the character of the mineralizing solutions after deposition of the jasper. Floors of many of the cavities are covered with corroded angular jasper fragments cemented by the younger minerals.

The *agate* coats the walls and roofs of the cavities and on the floors grades into flat intercalated layers of opal and chalcedony in the form of *onyx*. The thickness of the agate layer rarely exceeds an eighth of an inch, but some onyx masses are several inches thick. Agate and onyx were deposited contemporaneously. The greater thickness and flat layering of the onyx indicate gravitative control.

Green *chalcedony* is colored by small amounts of a disseminated, dendritic, amorphous, yellow-green isotropic material, probably consisting of a mixture of opal, allophane, and chloropal (Fig. 9A). Chemical tests of this material gave widely divergent results, but water, silica, aluminum and iron were repeatedly detected in samples. Opal was determined by its index (1.42 to 1.44); optical and chemical tests suggest the presence of allophane and chloropal (hydrous aluminum and iron silicate).

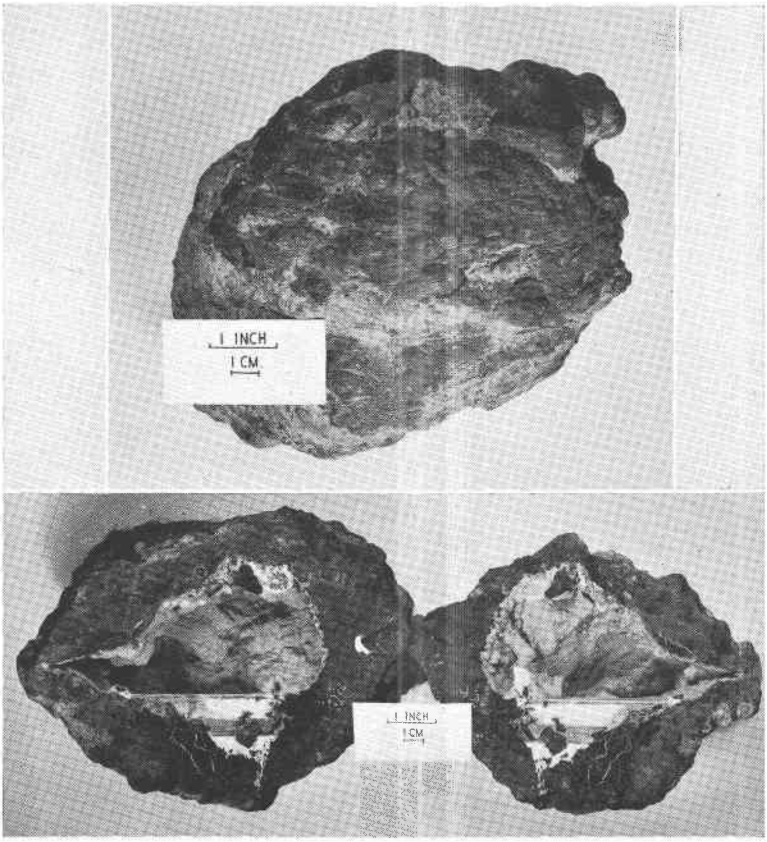

FIG. 5. Concretion partly filled with agate and onyx. Specimen Mountain. Upper view shows concretion as it appeared when found. Lower view shows the same concretion after it had been broken open. Onyx consists of alternating layers of opal (white) and chalcedony (gray).

The *opal* is generally opaque white or yellowish-white; in some specimens it is transparent and of inferior gem quality. It is commonly interlayered with the chalcedony, but in some specimens tiny anastomosing veinlets have entered the walls of the concretions. Some opal occurs in pulverulent white masses completely filling cavities in the jasper. Rarely, massive white opal completely fills the interior of a concretion.

Platy *calcite* in flat rhombohedrons is present in hemispherical aggregates, or isolated crystals in some of the concretions. It is an early min-

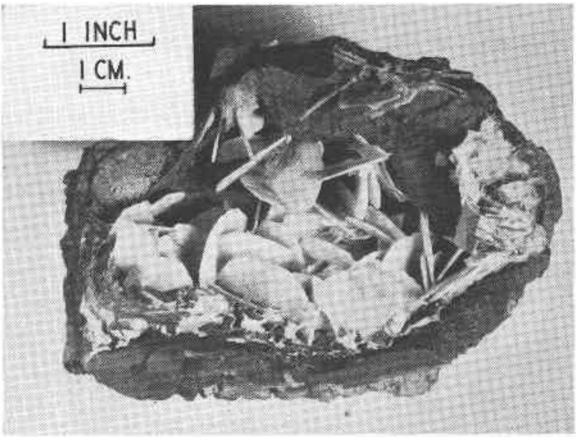

FIG. 6. Concretion containing chalcedony and opal pseudomorphs after calcite. Inner walls of concretion are coated with layered chalcedony and opal. Specimen Mountain.

eral and was deposited simultaneously with early generations of opal and chalcedony. Much of the calcite has been leached out of lamellar intergrowths with opal and chalcedony and has left porous platy aggregates

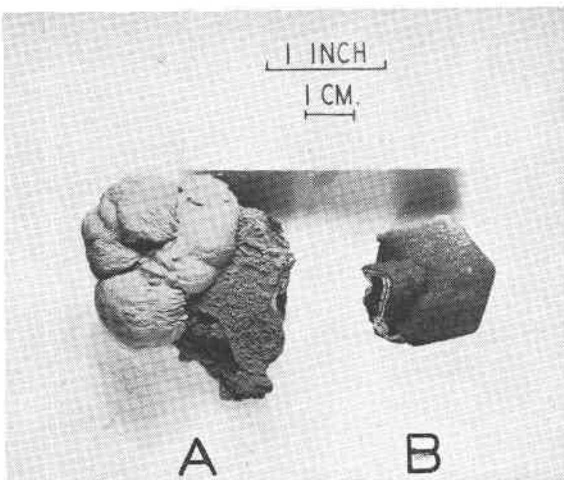

FIG. 7.

A. Chalcedony pseudomorphous after platy calcite aggregate.

B. Chalcedony and opal replacing and coating single tabular crystal of calcite.

of these minerals (Fig. 8). Later generations of opal and chalcedony locally have coated or replaced the calcite and form delicately banded pseudomorphs (Figs. 6 and 7).

Under the microscope it is seen that the calcite was deposited in at least two generations. The chalcedony and opal are birefringent (Fig. 9) and exhibit banded or feathery colloform structures. Angular and subgraphic intergrowths of platy calcite and chalcedony are abundant. Pseudomorphs of chalcedony and opal attest to the original presence of much calcite. Most of the replaced calcite was early and adhered to the walls of the cavities.

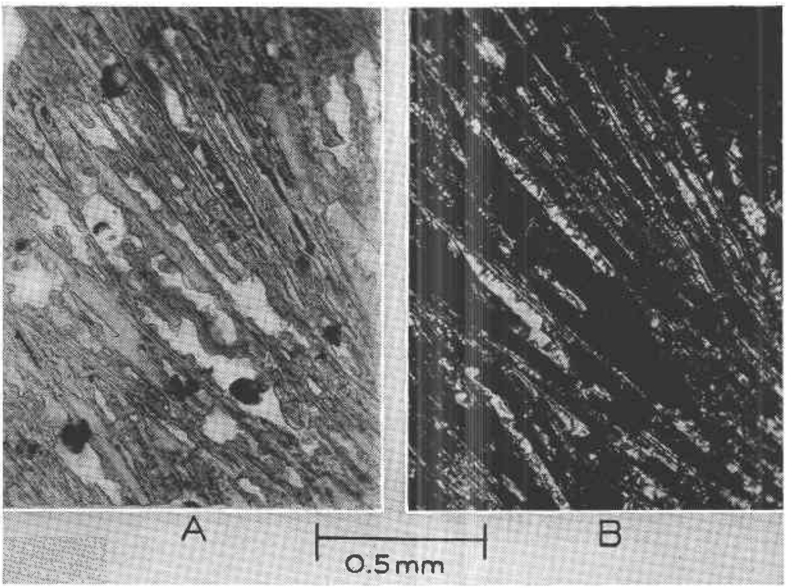

FIG. 8. Photomicrographs of thin sections of platy opal in porous aggregate from which interlaminated calcite has been dissolved. A second generation of opal coats the walls of the cavities originally occupied by calcite.

A. Plain light. White patches are cavities.

B. Crossed nicols. Note birefringent character of opal.

Paragenesis

Jasper replacement of pitchstone layers marked the inception of hydrothermal mineralization. Change in the character of the solutions caused dissolution of the interiors of many isolated concretions of jasper, and was followed by deposition of calcite, chalcedony, and opal in the interiors of the concretions. Calcite was an early mineral and was deposited in at least two generations. Chalcedony and opal, forming simultaneously with the calcite, in part replaced it. Pulsating deposition of the silica minerals, as shown by the banding, continued after the cessation of calcite precipitation. Late chalcedony, colored green by an amorphous mixture of opal, allophane, and chloropal, closed the period of mineralization.

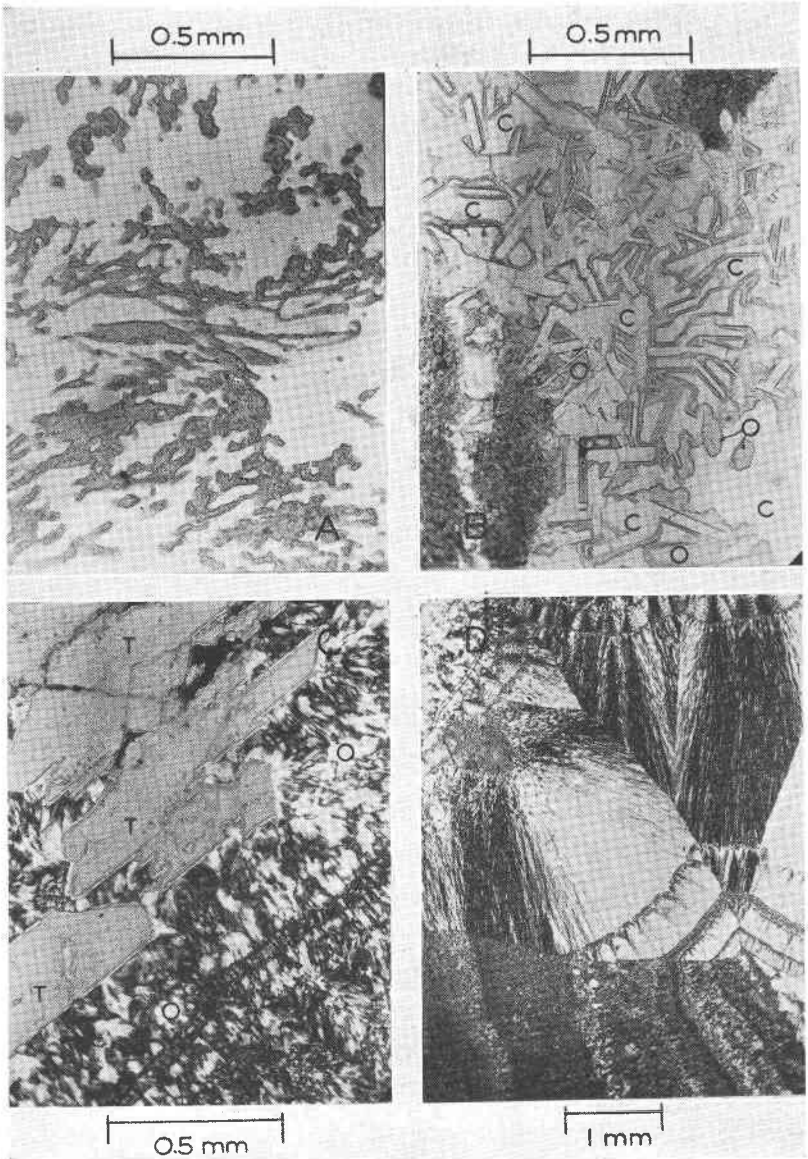

FIG. 9. Photomicrographs of thin sections of minerals in concretions.
A. Dendritic masses of chloropal and allophane in chalcedony (colorless). Plain light.
B. Chalcedonized intergrowth of opal (O) and platy calcite. Chalcedony (C) has completely replaced original calcite which rested on jasper walls of concretion. Plain light.
C. Intergrowth of platy calcite (T) and colloform birefringent opal (O). Crossed nicols.
D. Layered, birefringent chalcedony showing feathery colloform structures. Crossed nicols.

Solution of calcite from intergrowths with opal and chalcedony may have been caused by surface water but deposition of additional silica on the walls of casts of the calcite suggests that removal of calcite was caused by hypogene solutions.

Origin and Character of Mineralizing Solutions

Thrust fault zones cutting the volcanics are highly brecciated, exposing the area to localized warm or hot mineral-bearing solutions rising from depth. Mineral deposition came late in the igneous history of Specimen Mountain for the faulting occurred only after the volcano had become extinct. The rocks in the conduit were at least cool enough to serve as rigid bodies to the forces causing the faulting. Sufficient time elapsed between the periods of ejection of lava and pyroclastics and the formation of mineral deposits to permit a prolonged period of thrust-faulting.

The mineral-bearing solutions were probably warm waters deriving their heat from hot rocks near the source of the volcanics. The transported mineral load may have been in part a contribution from the rocks at the source of the waters, and in part material dissolved from the wall rocks of the channelways. As the solutions issued at the surface they probably had all the characteristics of the hot springs abundant in many regions of expiring volcanic activity.

Early precipitation of calcite suggests nearly neutral or alkaline waters, but partial resolution of calcite suggests a change to a more acid nature toward the end of the period of mineralization. In any event, the mineral solutions were probably pulsating in character, both as regards chemical composition and rate of flow.