Unusual Mineralogy of the Crystal Pit Spatter Cone, Craters of the Moon National Monument, Idaho.

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ABSTRACT

Crystal Pit Spatter Cone lies on the Idaho Rift System of the Snake River Basin Lava Plateau in south-central Idaho. The former magma chamber under the spatter cone, about 80 feet long and 35 feet wide, is still open for examination. It is reached by a descent of 90 feet through the narrow spatter cone throat. The magma chamber contains large quantities of the secondary sulfate minerals gypsum, mirabilite, and jarosite, all of which seem to be scarce or absent in caves in other volcanic regions. The gypsum and mirabilite probably were deposited from mineralized capillary groundwater seeping into Crystal Pit, rather than by condensation from mineralized volcanic gasses. However, the basaltic rocks overlying Crystal Pit seem to be poor in calcium-, sodium-, and sulfur-containing primary minerals that could be leached by the capillary groundwater. This extensive mineralization has occurred within the past 1000 to 2000 years.

Introduction

Few data have been reported on the secondary mineralization of volcanic caves in the United States. Secondary calcite mineralization, so common in limestone caves, is scarce or absent. The description of coralloidal opal from the ceilings of lava tubes in Lava Beds National Monument, California by Swartzlow and Keller (1937) is the only other report known to me concerning extensive secondary mineralization in a volcanic cave in the United States. The purpose of this paper is to describe Crystal Pit and to bring its minerals to the attention of interested speleologists and mineralogists.

History of Exploration

The earliest known exploration of Crystal Pit was that of Bob Limbert, in 1922. Limbert explored the lava plains around the Monument and published an article describing them in the March, 1924 *National Geographic Magazine*. Samuel A. Paisley, the first custodian of the Monument, probably entered the pit in 1925. Paisley displayed crystal-coated rocks, probably from Crystal Pit, for Monument visitors in 1926 (mentioned in the first of the *Superintendents Monthly Narrative Reports*). The geologist H. T. Stearns, who may have entered the pit in 1927 or '28, included a description of the pit in his unpublished manuscript on the geology of the Monument (Stearns, 1926-1928). A photograph by Paisley of the interior of the Crystal Pit was included by Stearns in his guide to the Monument (1959). R. C. Zinc (1956), in a short history of the Monument, reported that Boy Scouts from Pittsburgh, Pennsylvania, explored the pit to a depth of 163 feet in 1931 and found no floor. There are no other recorded explorations before mine of 1961 and '62.

Description of the Crystal Pit

Crystal Pit (Fig. 1) consists of the throat and empty lava chamber of a spatter cone (Fig. 2). Spatter cones are formed directly over lava-containing fissures by accumulated clots of expelled lava. The clots partially fuse and adhere to one another after falling. Spatter cones are not known to exceed 100 feet in height and rarely are more than 100 feet wide. They usually are formed during the closing stages of eruptions of degassed, viscous, basic lavas. Occasionally, the throats of spatter cones are open, but ones in which the magma subsided sufficiently before cooling to reveal the magma chamber are very rare.

Beginning at the southeast side of Big Crater Butte Cinder Cone, at Craters of the Moon, a chain of 11 spatter cones five to 50 feet in height trends southeastward. The chain is said by Stearns (1959) to be one of the most-nearly perfect in the world. None of the cones in the chain has an open throat except Crystal Pit. The first and second cones formerly could be entered to depths of 35 and of 50 to 60 feet, respectively, but both now are blocked by debris. Peck (1962) gave additional information about these cones.

Crystal Pit has an opening at the top about three feet in diameter. The throat maintains a circular cross-section for 60 feet, by which point it has become six to seven feet across. It resembles a well with walls of lava. It then abruptly bells out into a chamber 30 feet high (Fig. 3). The chamber is about 35 feet wide and 70 to 80 feet long. Its long axis represents the northwest-southeast trend of the rift from which the lava originally flowed. Extensive deposits of mirabilite and patches of gypsum occur in the chamber.

The floor of the chamber is formed almost entirely by loose cinders and lava talus. A five- to eight-foot wide ledge about 10 feet above the bottom was formed by a lava pool which cooled at this level. When the pool subsided, the ledge was left marking its former shoreline. There are indications of four other, less well-developed, lava-pool levels. In a southeasterly direction, the chamber soon ends in a small room where the ceiling descends to meet the floor. The ceiling here is covered by extensive deposits of mirabilite. To the northwest, the cave floor descends to a point 120 feet below the entrance and the chamber narrows to a passage 10 feet high and 60 feet long (Fig. 4). Sterns (1926-1928) suggested that from this lower passage, molten lava escaped to feed the margin of the flow surrounding Crystal Pit. Mirabilite and gypsum are abundant at the end of the passage and jarosite is common as a layer of powdery, loose, yellow material on

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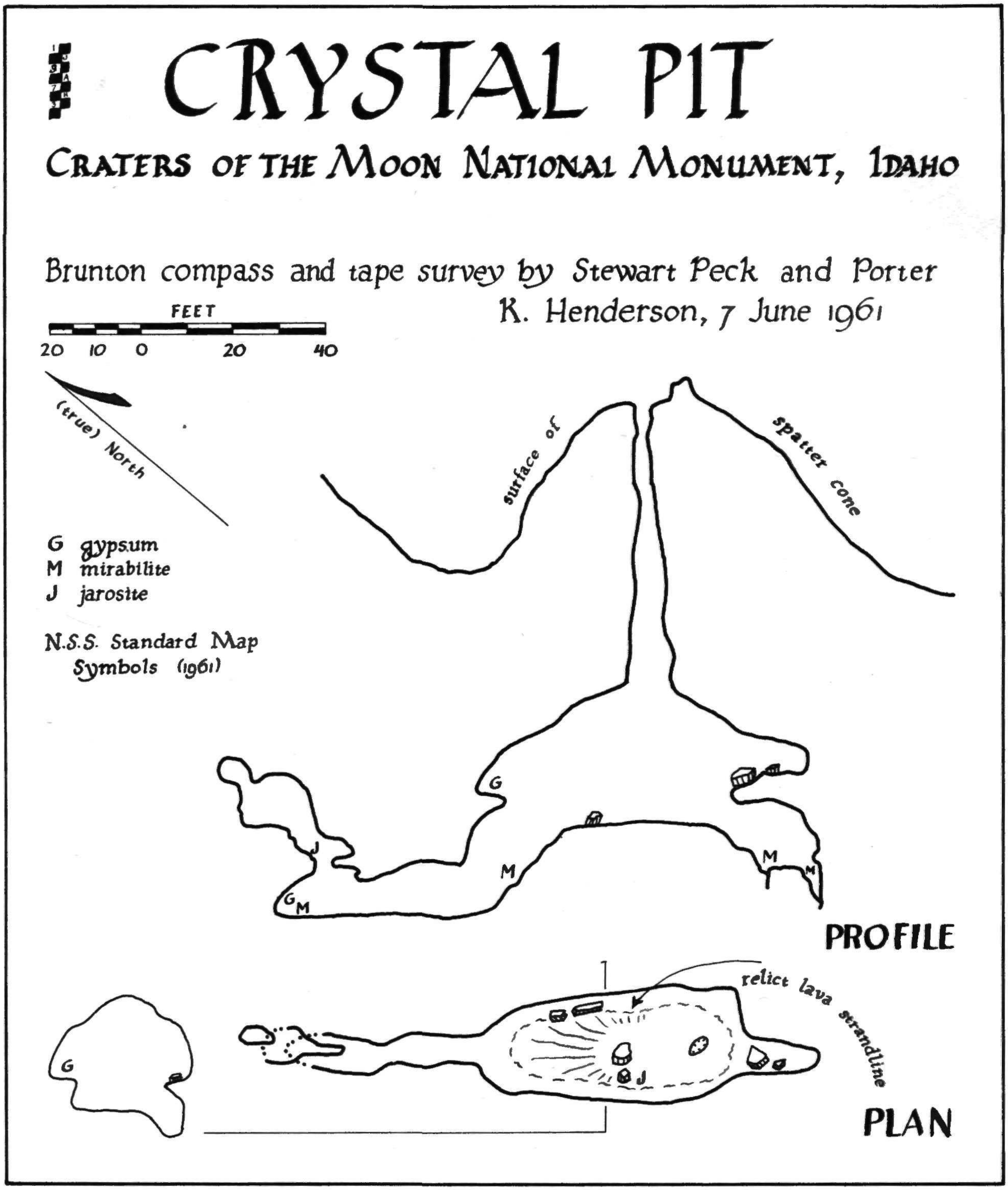

Fig. 1. Map of Crystal Pit.

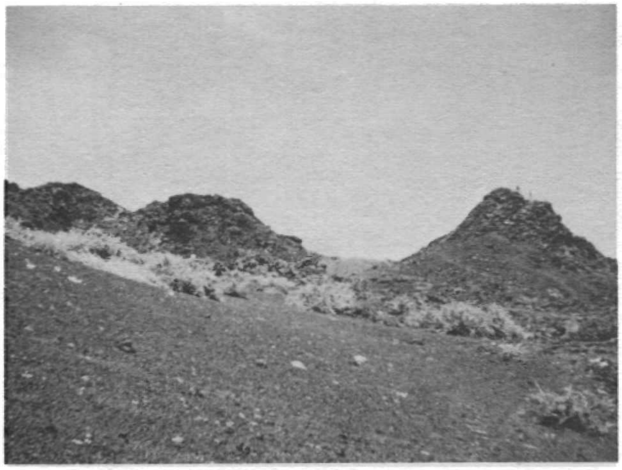

Fig. 2. Portion of spatter cone chain, Craters of the Moon National Monument, Idaho. Crystal Pit Spatter Cone on the right.

the floor. Above the termination of the passage is a hole leading upward into a small chamber. Still another, smaller, chamber lies above that one. The walls of the chambers are three-inch thick crusts of lava, behind which are red, unfused cinders. These chambers probably underlie the adjacent spatter cone.

The walls, the ceiling, and the underside of the lava-pool ledge bristle with sharp lava stalatites, of which a few are nearly 12 inches long. Gypsum crusts cover many of the stalactites, at times so completely that their basaltic

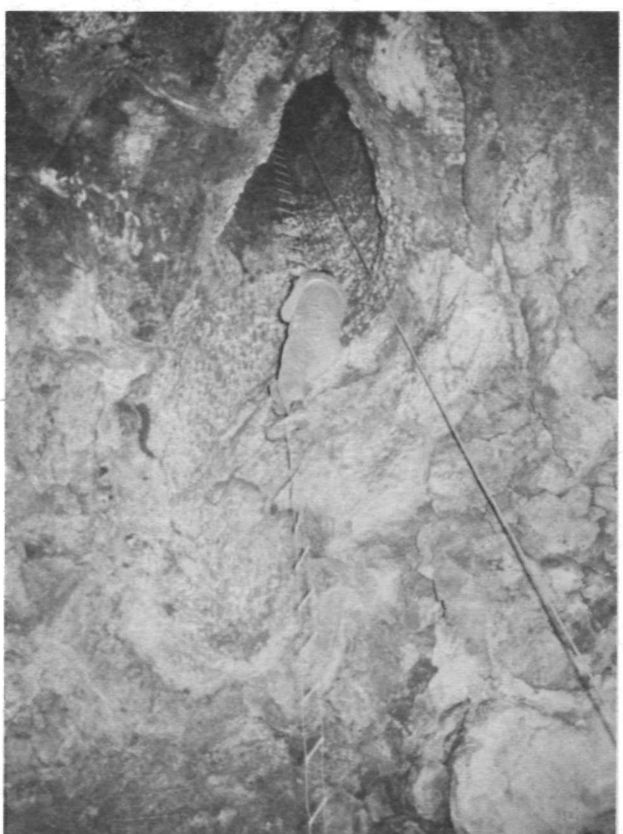

Fig. 3. Interior of Crystal Pit, showing junction of spatter cone throat and magma chamber.

Fig. 4. Northwest end of magma chamber and entrance to northwest passage, showing mineral crusts—especially, those concentrated along fractures in the wall rock.

cores are obscured. Crusts also occur on the wall and on the floor. The crusts are composed of individual, simple, monoclinic crystals up to one inch in length (Figs. 5, 6) The crystals average about 1/8 inch long and have well developed crystal faces. Gypsum needles and gypsum hairs were not observed.

Description of the Minerals

Gypsum ($CaSO_4 \cdot 2H_20$)

This mineral frequently occurs in limestone caves, but seemingly is rare in lava tubes. Its mode of occurrence in Crystal Pit was described in the preceding paragraph. Gypsum occurs in other spatter cones in the series including Crystal Pit (Peck, 1962), also, and in Great Owl Caverns lava tube.

Mirabilite ($Na_2SO_4 \cdot 10\ H_20$)

This unstable, hydrated sodium sulfate is known from caves and, also, from protected sites in recent lavas (Palache, Berman, and Frondel, 1951). It occurs as stalactitic masses in the Flint Ridge Cave System, Mammoth Cave National Park, Kentucky. Mirabilite is the stable phase in the system Na_2SO_4 - H_20 and forms below 32.38°F. Above this temperature, it becomes unstable and can change to thenardite. My sample was carried, sealed and under refrigeration, to Menlo Park, California for analysis. When not thus protected, and when occurring in warm or dry caves, the water is lost from mirabilite and thenardite results. The deep

Fig. 5. Mirabilite on lava slope. Jarosite lies as a loose powder on the mirabilite toward the bottom of the view. Carbide lamp provides scale.

Fig. 6. Mirabilite on walls, gypsum crystals on wall in lower right and lower left.

caves of the Monument are environmentally suitable for this sensitive mineral because their temperatures range from 28° to 35°F (the temperature of Crystal Pit was not measured).

The presence of thenardite in the Monument previously had been determined by analysis at the University of Utah. Also, both the hydrated and dehydrated phases are known to occur in the Monument in Arco Tunnel, Snow Cone, Lava River Cave, Indian Cave, and Great Owl Caverns.

Mirabilite deposits in Crystal Pit (see map, Fig. 1) occur as massive, efflorescent crusts. The crystals are so small that they are not visible to the eye. Neither crystals nor stalactitic deposits were noticed. The crusts are up to 6 inches thick and often cover areas greater than a square yard. Some of the crusts contain rounded depressions and other irregularities, as though they had been eroded by flowing or dripping water (Figs. 5, 7, 8).

Jarosite ($KFe_3(SO_4)_2(OH)_6$)

This mineral occurs as a widespread, ocherous to dark brown, secondary crust and coating on ferruginous ores and in cracks in the adjoining rocks. It has an appearance similar to that of limonite. It has not been noted from limestone caves or from basaltic lava flows (Palache, Berman, and Frondel, 1951). In Crystal Pit, the mineral was collected as a pale-yellow efflorescence mixed with gypsum, lying loosely on the floor and clinging to the walls (Fig. 5). Conspicuous deposits are found in the northwest corner of the large chamber and in the upper levels of the northwest passage.

Calcite ($CaCo_3$)

Thin, white crusts of what may be this mineral occur as patches on the walls of the large chamber. The material resembles the coralloidal opal of Swartzlow and Keller (1937), but effervesces with the application of hydrochloric acid.

Origin of the Minerals

Stearns (1926-1928) suggests that the gypsum in Crystal Pit may have been deposited from gaseous emanations accompanying the closing phase of the eruption, because gypsum is one of the common salts deposited at volcanic vents, or, alternatively, that sulfur compounds may have reacted at the orifice with calcium compounds in the deposits comprising the vent. Such mechanisms, however, are not likely to have brought about the large deposits of mirabilite because of thermal stability considerations, the limited amount of sodium compounds in the surrounding lavas, and the rarity of sodium compounds in vent emanations. Curiously, Stearns does not mention the presence either of mirabilite or of thenardite in Crystal Pit.

In my opinion, the minerals gypsum and mirabilite probably were deposited from capillary groundwater as secondary crystallization products, rather than from a gaseous carrier. Stearns (1926-1928, p. 75) reports a deposit of thenardite containing traces of K, Ca, Cl, and H_2O from

Indian Tunnel at a spot where water drips on sheltered ledges and evaporates, leaving a fluffy, white flour 1 to 2 inches thick. Likewise, the presence of mirabilite in limestone caves argues against deposition from heated vent gasses. If capillary groundwater supplied the ions for mineral growth, the process undoubtedly would have been very slow and regular, for the mineral deposits include no features suggesting growth rings or layers.

Several facts seemingly support an alternative hypothesis that the gypsum and mirabilite were precipitated from a sulfate-rich lake formerly existing in Crystal Pit. These are: the large size of the gypsum crystals, the absence of gypsum growths like those found in limestone caves, and the fact that both gypsum and mirabilite are precipitated from lakes in arid regions. This explanation is very unlikely, however, because the extremely porous and fractured rocks would not allow a lake to form.

If, as I suppose, the minerals were deposited from capillary groundwater slowly moving into an air-filled Crystal Pit, problems still would remain concerning the source of the minerals, their concentration, and their rates of deposition. The logical source of the minerals is the overlying lava. Recent lava from the Big Cinder Butte flow, some two miles from Crystal Pit, may be chemically similar to that of the Crystal Pit area. Stearns (1930) reports the percent composition of the entire sample of Big Butte lava to be: calcium oxide, 6.5%, sodium oxide, 3.59%; potassium oxide, 2.33%; ferric oxide, 2.15%; ferrous oxide, 12.97%. The sulfur source may have been the 0.15% iron disulfide, the only sulfur compound reported.[1] It seems to me that these quantities are low and that they would not provide a sufficient amount of elements to the groundwater. However, the unweathered lava may contain primary minerals which are sufficiently soluble in rainwater to provide the elements being considered. As the mineralogic composition of the lava is not reported, the solubility of its constituents can only be guessed at.

Another possibility is that these compounds may have been carried up into the cave from buried evaporite deposits by groundwater, but this seems unlikely under the circumstances. Malde (1965) presents a discussion of the stratigraphy of the region and other information pertinent to this problem.

The ages and rates of deposition of cave minerals often are of interest. Seemingly, the unusual minerals in Crystal Pit were deposited relatively rapidly and relatively recently. The appearance, degree of weathering, and vegetal cover of the Crystal Pit flow are very similar to those of the King's Bowl Rift flow, 35 miles to the south. The age of King's Bowl flow has been found to be 2130 ± 130 years before the present (Prinz, 1970), by means of C^{14}-dating of carbonized sagebrush at its base. Tree-ring data from the Monument also suggest that the youngest flows, including the Crystal Pit flow, are 1000 to 2000 years in age (Stearns, 1959 and unpublished).

[1] I have been given figures only for the elements under discussion here.

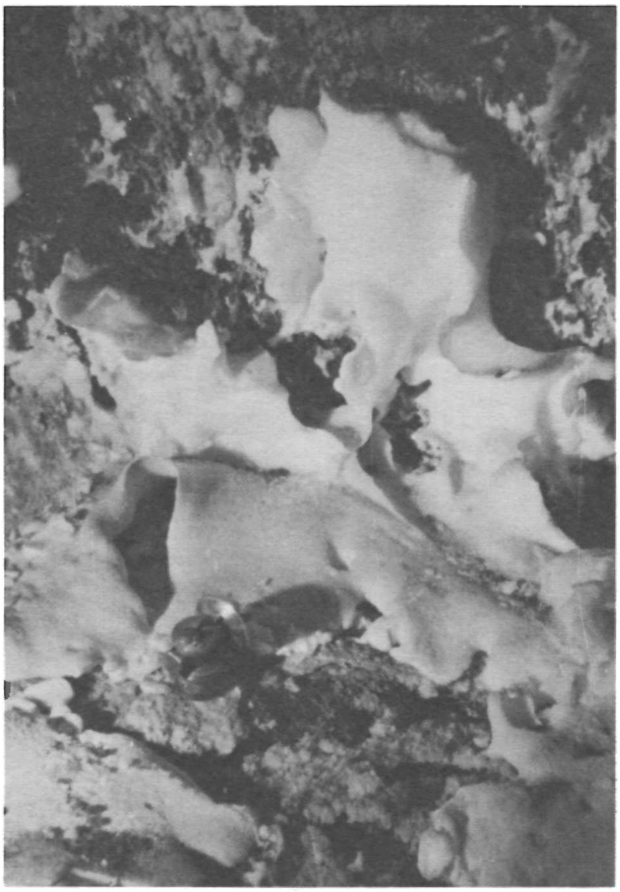

Fig. 7. Mirabilite on floor of pit. Carbide lamp provides scale.

Fig. 8. Gypsum crystals on wall and covering tips of lava stalactites.

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