ORIGIN OF SPHEROIDAL CLUSTERS OF ANALCIME FROM BENTON COUNTY, OREGON

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ABSTRACT

An unusual occurrence of analcime has been found at Coffin Butte, Benton County, Oregon. Trapezohedrons of analcime are arranged in spheroidal clusters with hollow centers. Natrolite occurs as acicular prismatic crystals completely enclosed within the analcime. The arrangement of the natrolite indicates that it originally radiated from the now hollow centers of the clusters.

The spheroidal clusters, which often appear only as rings of crystals, are not due to cyclic twinning as has been suspected, but the grouping probably has been controlled by the radiating structure of the natrolite. The steps in the development of a spheroidal arrangement of this type can be seen from a study of perched crystals. With analcime perched on natrolite as a starting point, further growth of the analcime and removal of the unprotected natrolite would produce spheroidal clusters of analcime such as were found at Coffin Butte.

INTRODUCTION

Many fine specimens of zeolites have been obtained from a basalt quarry on Coffin Butte, located about 10 miles north of Corvallis in Benton County, Oregon. The Butte lies adjacent and to the west of U. S. Highway 99 W., and is about one mile south of the Polk county line. It stands out as a prominent topographic feature rising 500 feet above the flood plain of the Willamette River. It is elliptical in plan with its major axis about one mile long and trending northeast-southwest. There are numerous quarries in the Butte from which rock was obtained for road ballast for Camp Adair. The presence of well defined pillow structures with radial jointing in the basalts, and numerous small beds of intercalated sandstone, indicate that the basalt was extruded in several flows with short periods of quiescence between. The age is early Tertiary, probably Eocene.

Well crystallized specimens of stilbite, mordenite, mesolite, natrolite, heulandite, chabazite, apophyllite, and analcime were obtained from veins, brecciated zones, and gas cavities at various localities on the Butte. The best specimens collected to date have come from a quarry at the north east end of the Butte. At this place the deposition was limited to the following, arranged in their order of deposition: natrolite, analcime, stilbite, apophyllite, and finally chabazite.

Among the most interesting of the zeolites from Coffin Butte were clusters of analcime crystals which had been called "cyclic twins" by local collectors. The writer studied these groups of crystals in an attempt to determine their origin.

Description of Clusters

The individual analcime crystals are trapezohedrons, without modification, varying from about 2 mm. to 12 mm. in diameter, the average being about 5 mm. in diameter. They have low birefringence and an index of refraction of 1.486±0.001. The analcime shows very irregular double refraction and some complex twinning, often polysynthetic. One type of anisotropism, observed in thin sections, consists of an isotropic cross which divides the area into quadrants with negative elongation. Usually the dark cross maintains a constant position and rotates with the stage, all quadrants extinguishing almost simultaneously. However, in some cases the cross remains parallel to the cross-hairs during the rotation of the stage, as in spherulites. Numerous careful studies have been made on the causes of the anomalous double refraction in analcime, the outstanding pioneer work being that of Ben-Saude (1), and Klein (2). These writers concluded that analcime was isometric and explained the double refraction as being due to internal tension set up as a result of change in temperature. The Coffin Butte analcime provided an opportunity to determine whether mechanically produced strain during growth might play a part in causing the double refraction, since it would be expected that the analcime with inclusions would show the most strain and consequently most double refraction. This was not the case, there being equally as much double refraction in the analcime which had no inclusions.

The clusters of analcime are fairly uniform in size, averaging about 12 mm. in diameter (Fig. 1). Most of the clusters appear to be cyclic, often forming a complete circle with hollow center (Fig. 2). Actually these circular groups are sections of hollow spheroids, and in a few cases almost completely closed spheroids were found.

The clusters rest on a cavity coating of nontronite, and occasionally the nontronite is included in the analcime crystals. The nontronite has a radiating spherulitic structure and shows considerable pleochroism, from deep brown to greenish gray. The maximum and minimum indices of refraction are 1.615±0.003 and 1.574±0.003 on the best material. From other parts of the Butte, material of lower indices of refraction was obtained, indicating the presence of other members of the nontronite-beidellite series. Microchemical tests of the nontronite showed the presence of large amounts of magnesium, iron, and silicon, with smaller amounts of calcium and aluminum. The nontronite was probably derived from the basaltic glass, which commonly forms crusts around the basalt pillows, and then migrated to its present location under conditions such as described by Allen and Scheid (3). Although most of the nontronite was deposited before the formation of the zeolites, a small

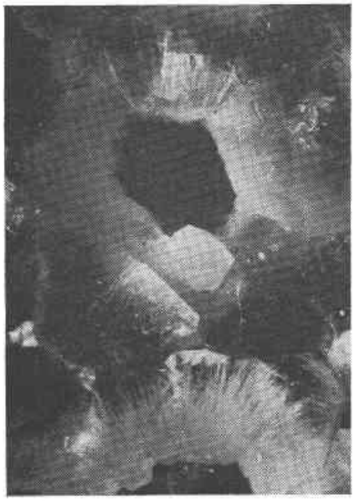
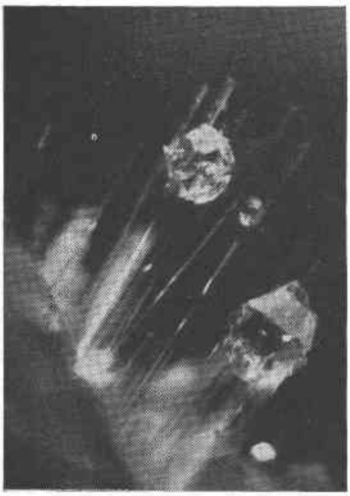


FIG. 1. Spheroidal clusters of analcime from Coffin Butte—×3½.
FIG. 2. Clusters of analcime crystals with natrolite radiating from centers. Coffin Butte—×5.



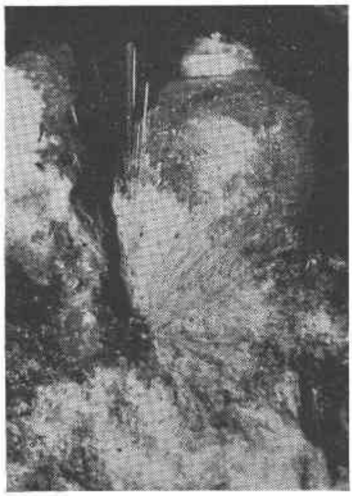


FIG. 3. Analcime perched on natrolite, from Coburg quarry—×30.
FIG. 4. Radiating group of natrolite crystals partly enclosed by analcime, from Coburg quarry—×5.

amount came later indicating that the period of migration and deposition was not a short one.

The analcime crystals contain inclusions of a white acicular mineral which radiates from the hollow centers of the spheroidal clusters and produces a white turbid area around these centers, sharply contrasting with the clear colorless areas that are without inclusions (Fig. 1). The enclosed acicular crystals average about 2 mm. in length and in thin section show distinct alteration rims about them. It is probable that this alteration is largely responsible for making the acicular prisms so clearly visible within the analcime (Fig. 2). The alteration makes it difficult to obtain satisfactory Becke line tests. However, oriented sections cut normal to the prism zone give symmetrical extinction and good interference figures, which together with the other optical properties prove the mineral to be natrolite.

A partial spectrographic analysis was made of an analcime crystal with its natrolite inclusions and the result showed less than 1.0% calcium, indicating that both the analcime and natrolite were very low in calcium.

It was observed that in no case were spheroids present without having inclusions of natrolite in them, and in every case the natrolite needles radiated from the hollow centers of the spheroids.

The question as to whether the natrolite pierced or replaced the analcime, was formed at the same time as the analcime, or was enclosed by growth of the analcime is important in any consideration of the origin of the clusters. A suggestion as to the solution of this problem was given by observations on some perched crystals from other localities.

Perched Crystals

The perched habit for zeolites and closely related minerals has been considered fairly rare. In a discussion of the minerals of the New Jersey diabase, Levison (4) describes supporting "flexible filaments" of "probably a fibrous natrolite" with "parasitic" crystals of "calcite, datolite, apophyllite or other minerals." Murdoch and Webb (5) mention an unusual case from Red Rock Canyon, California where " . . . a few sharp natrolite crystals have analcite crystals perched on the natrolite terminations." Recently the unusual occurrence of cristobalite and quartz perched on mordenite has been described from India (6). The writer has found several good examples of perched zeolites recently, such as chabazite perched on mordenite from near New Era, Oregon, and a similar occurrence from Kalama, Washington (Fig. 5). Chabazite also occurs perched on mesolite on the Oak Grove Fork of the Clackamas River, Oregon, and on natrolite at Coffin Butte. Laumontite is found perched on mesolite at New Era. The most interesting combination from the standpoint of this study was the analcime perched on natrolite from Coburg quarry, located about five miles north of Eugene, Oregon, on the northeast bank of the McKenzie River (Fig. 3).

In the material studied from Coburg quarry, all gradations have been noted from small analcime crystals perched near the top of the natrolite needles, to specimens in which the analcime crystals have diameters almost equal to the length of the natrolite needles. Other specimens show the natrolite in radiating masses with analcime crystals perched in an arc. Figure 4 shows an intermediate stage with analcime enclosing some radiating natrolite crystals while others remain free. It is believed that these perched crystals, and examples of natrolite partly enclosed in analcime, represent a stage through which the spheroidal clusters passed in their formation.

The study of perched zeolites, in addition to its direct bearing on the origin of the analcime clusters, is of interest because of the possibility of deriving data on selective perching as a special type of selective incrusta-

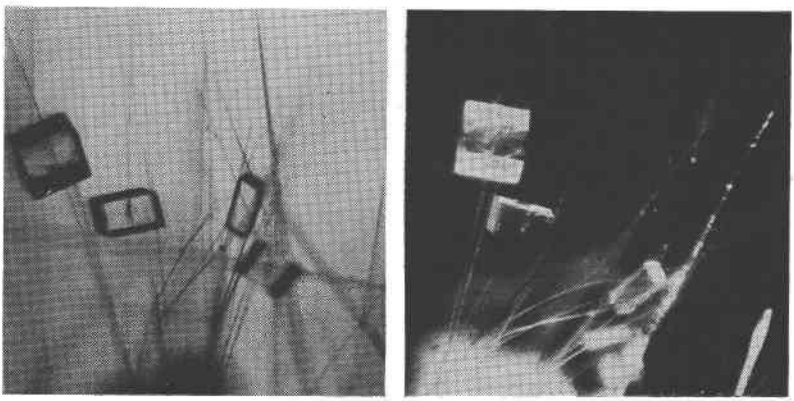


FIG. 5. Chabazite perched on mordenite from Kalama, Washington. Left photomicrograph made with substage lighting. Right with reflected light—×19.

tion, and directed orientation of crystals. To date, a sufficiently large number of occurrences of perched zeolites have not been found to permit deriving general conclusions, but the careful study of new localities should provide more data.

From the limited number of examples of perched zeolites studied, it appears that almost any combination of zeolites may produce perched crystals, and the acicular zeolites often form mounts for calcite and other non-zeolite minerals.

It was considered possible that there might be some preferred orientation of the perched zeolites on the supporting stalks. In Fig. 3, it appears that the analcime has oriented itself with a 4-fold axis parallel to the natrolite prism zone, and in Fig. 5 there seem to be numerous examples of chabazite rhombohedrons arranging themselves with a face parallel to a mordenite crystal. However, observations on numerous other perched crystals proved there were a great many exceptions to these orientations and no generalizations can be made from this material regarding preferred orientation of the perched crystals.

In the case of two prismatic zeolites, parallel or near parallel growth often takes place. Scheit (7) noted a case of thomsonite enveloping natrolite with the *c* axes parallel but a very slight non-parallelism of the corresponding thomsonite pinacoids and natrolite prism faces. At Coffin Butte, a good example of crystals of natrolite terminated by mesolite was found. The dividing line between the two species was a sharp angular line and could be seen in ordinary light, although there was no change in the outline of the crystal. Under crossed nicols the difference in birefringence made the change from one species to the other very distinct. At Coburg quarry the relations were reversed and many crystals had a mesolite base and natrolite termination. The lack of gradation between natrolite and mesolite gives further evidence that they are not completely isomorphous.

Penfield (8) studying analcime from the Phoenix Mine, found a secondary growth of analcime in partial parallelism with a core of earlier analcime. Due to the lack of complete parallelism the later analcime tended to break apart into octants.

Origin of Coffin Butte Spheroidal Clusters

At Coffin Butte, natrolite was deposited at an early stage, in radially arranged acicular crystals. The development of the spheroidal clusters of analcime probably was controlled by the natrolite in the following manner. With a change in the composition of the depositing solutions, marked by an increase in silica and a decrease in alumina and soda, analcime started to grow as perched crystals on the radiating natrolite. Growth of the analcime continued until the trapezohedrons made contact with each other. Where this growth was uniform and from equally spaced centers, almost perfect spheres formed. This was an exceptional condition, and in most cases more irregular spheroidal clusters, or only rings were formed. Oriented thin sections cut normal to the natrolite prisms show the presence of reaction rims which probably formed as the solutions changed and the analcime started to deposit. With continued change in the character of the solutions, the natrolite was no longer in equilibrium and was completely dissolved except where protected by the enveloping analcime. This resulted in the centers of the spheroidal clusters becoming hollow, and an absence of natrolite protruding from the outer surfaces of the analcime in the clusters. In no case were remnants of natrolite found in the center or projecting out of the spheroids.

Fenner (9) in his description of the zeolites of the Watchung basalt, reports the early formation of analcime and later crystallization of natrolite. He states (p. 165),

> The relations of analcite and natrolite are of especial interest because of the inferences derived from the application of the phase rule. It should be found that where the two exist together, one belonged to a period of higher temperature and remained stable until a definite transition point was reached, when it began to pass over into the other. It appears that this is true and that the direction of the change is from analcite to natrolite.

Fenner gives substantial evidence to prove that natrolite has replaced the analcime and he notes that the natrolite looks perfectly fresh while the analcime appears spongy and decomposed. At Coffin Butte the fact that the analcime is later than the natrolite is shown by the clear fresh appearance of the analcime and the alteration rims on the natrolite. The localization of the natrolite at the centers of the analcime clusters would likewise be difficult to explain if the natrolite had not preceded the analcime, since voids between clusters would have provided equally good positions for the attack on the analcime by the natrolite. Finally, the occurrence of analcime perched on natrolite is satisfactory evidence of the earlier formation of the natrolite. Although it is probable that analcime most often precedes natrolite, the reverse order has been recognized in several localities. At Snake Hill, N. J., in diabase closely related to the Watchung basalt, Levison (4) noted the order: "trap, pectolite, natrolite, and analcite." In this case analcime was sequent on natrolite and terminated pectolite, so the order should have been evident even without a microscope. At Coffin Butte, the earlier crystallization of natrolite seems sufficiently well established so that it may safely be used in an explanation of the origin of the spheroidal clusters described in this paper.

Conclusions

The spheroidal clusters of analcime found at Coffin Butte, Benton County, Oregon, are not cyclic twins but probably have been arranged under the control of the radiating structure of natrolite. The formation of the analcime produced only a mild reaction with natrolite, but further change in the character of the solutions caused complete solution and removal of the latter, except where protected by the analcime.

It is also probable that an intermediate stage in the formation of the spheroidal clusters was the growth of perched crystals of analcime on natrolite. This perched habit, which has been considered fairly rare, was found to be rather common at the zeolite localities in Oregon.

If the hypothesis of formation stated here is correct, we have another good example of one mineral directing the crystallization of another. There is also evidence of the change in composition of the depositing solutions with preservation of a less stable phase by inclusion in a more stable one, as the character of the solutions changed.

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