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ZEOLITE FILLING AND REPLACEMENT IN FOSSILS

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ABSTRACT

Zeolites are usually found filling vesicles and fractures in igneous rocks or as diagenetic minerals in sedimentary rocks. In an unusual occurrence near Eugene, Oregon, there is filling of cavities in gastropods and pelecypods with analcime, heulandite, and stilbite. There is also strong evidence of zeolitization of the shells, as well as the presence of zeolite casts. The zeolites were deposited by hydrothermal solutions related to a basalt dike which intrudes the fossiliferous strata, and a probable age of late Oligocene to early Miocene is suggested for the zeolitization. In a second locality, underlain by another intrusive, the zeolites filling and replacing fossils are heulandite and stilbite, rather than analcime, but the age is probably about the same as in the first described locality.

INTRODUCTION

A highway cut on Interstate Highway 5, east of Eugene, Oregon, was opened in 1952 and exposed highly fossiliferous Oligocene sandstone of the Eugene Formation. The highway cut is located in Section 3, T. 18 S., R. 3 W., about 0.7 miles southeast of Judkins Point. The sandstone contains marine fossils which are unusual in that some of them contain euhedral zeolites, principally analcime, inside those portions of the shells which were not completely filled with detrital material (Fig. 1). Of even greater interest is the zeolitization by heulandite and stilbite of some of the shells. This probably resulted from a process of simultaneous replacement similar to the calcification and silicification more commonly seen in fossils. Fossils containing zeolites are found in the sandstone on both sides of the dike for distances of at least 300 feet.

GEOLOGY OF THE HIGHWAY CUT

At the fossil locality, the curving highway has a tangent about N 55° W and cuts across a north trending ridge for a distance of 1250 feet. The cut slope has a maximum height of 50 feet and exposes a coarse bedded tuffaceous sandstone with a gentle (6°) dip to the east. Approximately half way through the cut there is a north-trending multiple dike of basalt about 50 feet wide, dipping steeply (70°) to the east. The dike has stringers which cut through the sandstone, and the contact effects on the irregular hanging wall are very strong. These consist of a contact zone with alteration products, shown by *x*-ray to be chiefly jarosite group minerals. The sandstone is metamorphosed to a dense hornfels. The dike is vesicular and only a very little calcite, chalcedony, and nontronite fill the few vesicles that contain minerals. Analcime, heulandite and calcite, with rare pyrite, fill small fissures, especially near the contact zone. Toward the center of the dike, the texture is diabasic and the rock consists of labradorite, augite, chloritized biotite, magnetite and accessory minerals. What is undoubtedly the extension of the dike appears again about a quarter of a mile to the north in a railroad cut. Here the dike is only eight feet wide, almost vertical, and shows less contact effects. In spite of this, the fossiliferous Eugene sandstone which has been cut by the dike exhibits considerable zeolitization of the fossils.

An attempt was made to determine whether there was a zoning of the zeolitization, with respect to amount and types, progressing away from

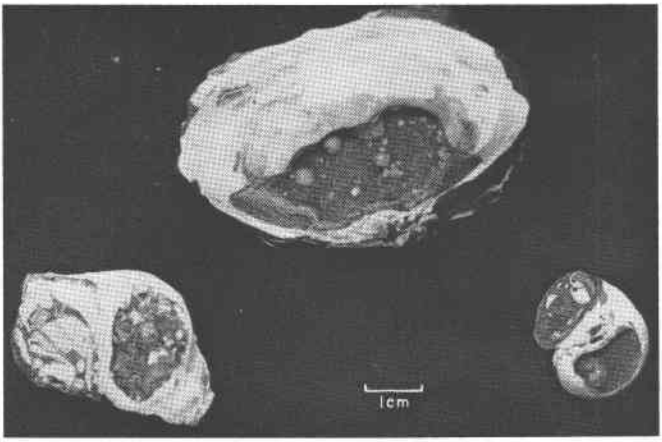

FIG. 1. Fossils with zeolites in cavities. Lower left, *Bruclarkia* with analcime cementing broken shell fragments. Center, *Spisula* with analcime crystals. Lower right, *Natica* with heulandite in cavity.

the dike into the sandstone. The lack of continuity of the outcrops and the pinching out of fossiliferous lenses prevents drawing any valid conclusions other than that there is no strong evidence of zoning. The distance of zeolites from the dike makes it appear that contributions of hydrothermal solutions from the dike moved vertically as well as along the bedding, possibly from tongues of the dike or from a large irregular mass at greater depth.

Description of Specimens

The fossils found in the two cuts are chiefly gastropods and pelecypods, the most abundant being the gastropods *Bruclarkia* and *Natica*, and the pelecypods *Pitar*, *Spisula*, *Solen*, and *Lucina*. Where these shells lack complete filling by detrital material, the remaining cavities frequently contain euhedral zeolites, calcite and nontronite. In addition, petrified wood with *Teredo* borings also may have analcime, heulandite and calcite lining the cavities. An unusual occurrence is a concretion containing a 3.5 by 1.0 cm crab claw at its center. Part of the shell of the claw has been removed and exposes a cavity filled with analcime and calcite crystals. In the gastropods it is very common to find an analcime crystal appearing in an opening at the apex of the shell where a cavity existed because the filling did not reach the tip of the spire. Some shells give no indication of the presence of zeolites in them until they are broken. In general, the gastropods are better zeolite bearers than the pelecypods, probably because it is more difficult for the detrital filling to work its way to the spire of the gastropods than to fill the interior of the pelecypods. However, if openings are left in the pelecypods, they are usually of greater size and will accommodate larger zeolite crystals. It is difficult to determine the per cent of shells which have zeolites in them at this locality, but even in the best collecting spots, less than 10% of the gastropods and only about 1% of the pelecypods are zeolite bearing.

The most abundant zeolite minerals present are analcime, heulandite and stilbite. The dominant form on the analcime is the trapezohedron, but sometimes there is modification by the cube. The analcime crystals range up to one centimeter in size and are vitreous and clear except where there are inclusions of shell fragments, heulandite or nontronite. Heulandite occurs as either euhedral crystals or radiating blades and may be colorless or pink. Stilbite is seen chiefly in thin sections where it has the epidesmine habit and exhibits greater strength of crystallization than the heulandite. Calcite also occurs as a cavity filling in colorless or honey colored rhombohedra or scalenohedra.

Among the less common minerals are minute crystals of pyrite and black colloform ball-like masses of nontronite.

Paragenesis

The gastropods and pelecypods lived in a shallow water, nearshore environment in an Oligocene sea. This is indicated by the genera present and also by the abundance of petrified, carbonized, and *Teredo* bored wood in some of the beds. The depositional environment was probably similar to that described by the writer for an area about 30 miles to the north where cubic pseudomorphs of quartz after halite occur in petrified wood (Staples, 1950). Those shells which were only partly filled with silt and sand frequently were broken before the zeolites were introduced as is shown by the inclusion of shell fragments in analcime crystals. It is possible that some of the beds close to the intrusion were disturbed by it and the shells broken, with subsequent cementing together of the fragments by the zeolites. When analcime encloses shell fragments they appear well preserved, as is the case with enclosed natrolite at Coffin Butte, Oregon

(Staples, 1946). The order of deposition of the minerals was (1) heulandite, (2) nontronite, (3) analcime and (4) calcite.

The zeolites, analcime, heulandite, and stilbite, are found in small amounts in the dike and sandstone, but occur mostly in the fossils. Analcime, the sodium zeolite, occurs in the shell cavities, while heulandite and stilbite, the calcium zeolites, occur as a shell replacement and less often than analcime as a cavity filling mineral. The evidence that heulandite and stilbite sometimes are a replacement of the aragonite of the shells

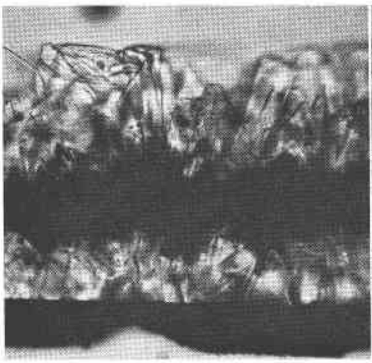

Fig. 2

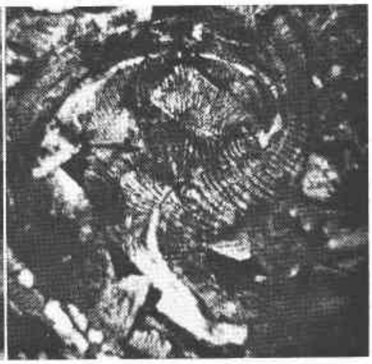

Fig. 3

FIG. 2. Photomicrograph of shell cross-section showing differential replacement of shell layers by heulandite. Dark areas are decomposed aragonite. Length of section 0.4 mm.

FIG. 3. Photomicrograph of replacement of gastropod by rectangular stilbite crystals. Curling shell structure can still be seen. Field size 2.8 mm. Polars crossed.

rather than a cast of the shells, consists of the following observations. (1) Broken shell fragments standing in open cavities are replaced by heulandite. It is unlikely that these cavities were ever completely filled with detrital material and under these circumstances the formation of a cast would be impossible, there being no mold to enclose it. (2) A microscopic examination of replaced shell fragments shows banding of heulandite parallel to the shell surface. Most shells are layered, and it is to be expected that prismatic and lamellar layers would undergo differential replacement. The layering is clearly evident in the replaced shells with some of the layers occasionally not being completely replaced (Fig. 2). (3) The replacing zeolites are the calcium minerals heulandite and stilbite, rather than analcime, the sodium zeolite. Where analcime encloses shell fragments they remain unaltered. This suggests that the aragonite of the shells may have supplied calcium, thus favoring heulandite and stilbite as the replacing minerals. (4) The irregular contact between heulandite or stilbite and the shell, where replacement is not complete and the zeolites are eating into the shell, contrasts sharply with the straight contacts of simple deposition such as between the shell and analcime. (5) In thin section, it is common to see relic shell structures remaining in the areas now occupied by stilbite and heulandite (Fig. 3).

Any one of the above criteria in itself might be insufficient proof of replacement but the combined evidence leaves no doubt that zeolitization represents a definite type of simultaneous replacement in the fossils.

Although the occurrence of diagenetic zeolites in sedimentary rocks is fairly common, as has been described by many writers (Coombs *et al.*, 1959; Deffeyes, 1959; Teodorovich, 1961), one can be certain that the occurrences described here are not of this origin. The diagenetic zeolites are usually the result of a low temperature reaction between the volcanic glass of sedimentary rocks at shallow depth with alkaline lake water or at greater depths with subsurface water. The result is widespread formation of zeolites throughout the sedimentary rocks. In the present case the tuffaceous sandstones are relatively free of zeolites in most places, with only the areas near an intrusive containing them. The presence of associated pyrite, rare in the sandstone away from the intrusives, and the strong contact effects, all point to the intrusives as a source of hydrothermal solutions. Nontronite and analcime are in the same relation as at Coffin Butte, Oregon, where the zeolites are associated with pillow basalts (Staples, 1946) and definitely of hydrothermal origin.

The age of the zeolitization is post-middle Oligocene as proven by the zeolitization of Eugene Formation fossils. The close genetic relationship with the intrusive dike suggests that the zeolitization took place at about the time of, or shortly after, the intrusion. The dike probably belongs to the Little Butte Volcanic Series which makes up the bulk of the Western Cascade Range. According to Peck *et al.*, (1964) the Series ranges from early or middle Oligocene to early Miocene, and local evidence favors an early Miocene age. The best approximation of the age of zeolitization is therefore late Oligocene or early Miocene, with preference for the later.

Gillespie Butte Occurrence

A second occurrence of fossils with zeolites is at Gillespie Butte in Sec. 19, T 17 S, R 3 W, about four miles northeast of the occurrence first described. Gillespie Butte also consists of Oligocene Eugene sandstone intruded by what has been described as a small phacolith with an estimated maximum thickness of 145 feet and occupying a local synclinal fold (Shaw, 1964). The zeolites are heulandite and stilbite, with analcime being rare. They are in the basalt as thin veinlets and in the sandstone as veinlets and filling of fossils. The zeolites are closely associated with pyrite, or more frequently with limonite pseudomorphs after pyrite.

Most of the voids in the fossils are filled with heulandite or stilbite rather than analcime and the shells are probably replaced by these zeolites. However, it is more difficult to prove simultaneous replacement of the shells rather than cast formation at this locality because of the weathered condition of the material. Most of the zeolitized fossils found to date have been dug up during excavations for graves in a small cemetery on the Butte. If there should be deeper excavation for buildings, it is probable that fresher material would be encountered.

Conclusions

Two occurrences of zeolitized and zeolite-bearing fossils are known in the Eugene area, Oregon. The zeolites, analcime, heulandite, and stilbite are found as cavity fillings, casts, and shell replacements in gastropods and pelecypods of Oligocene age. The sources of the hydrothermal solutions responsible for the zeolites are basaltic intrusives; a multiple dike in one case and a possible phacolith in the other. It is not completely understood why zeolitized fossils have not been found in association with the many other similar intrusives in the region. The age of the zeolitization is probably late Oligocene or early Miocene, although a possible younger age for the intrusives cannot be ruled out. Zeolitization as a type of fossilization is probably rare, but it is likely that careful search will turn up other occurrences.

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References

Coombs, D. S., A. J. Ellis, W. S. Fyfe and A. M. Taylor (1959) The zeolite facies, with comments on the interpretation of hydrothermal syntheses. *Geochim. Cosmochim. Acta* **17,** 53–107.

Deffeyes, K. S. (1959) Zeolites in sedimentary rocks. *Jour. Sed. Pet.* **29,** 602–609.

Peck, D. L., A. B. Griggs, H. G. Schlicker, F. G. Wells and H. M. Dole (1964) Geology of the central and northern parts of the Western Cascade Range in Oregon. *U.S.G.S. Prof. Paper* **449.**

Shaw, J. H. (1964) *Petrography and Petrology of Some Intrusive Bodies in the Southern Willamette Valley, Oregon.* M.S. Thesis, Univ. of Oregon.

Staples, L. W. (1946) Origin of spheroidal clusters of analcime from Benton County, Oregon. *Am. Mineral.* **31,** 574–581.

——— (1950) Cubic pseudormorphs of quartz after halite in petrified wood. *Am. Jour. Sci.* **248,** 124–136.

Teodorovich, G. I. (1961) *Authigenic Minerals in Sedimentary Rocks.* Consultants Bureau, New York.