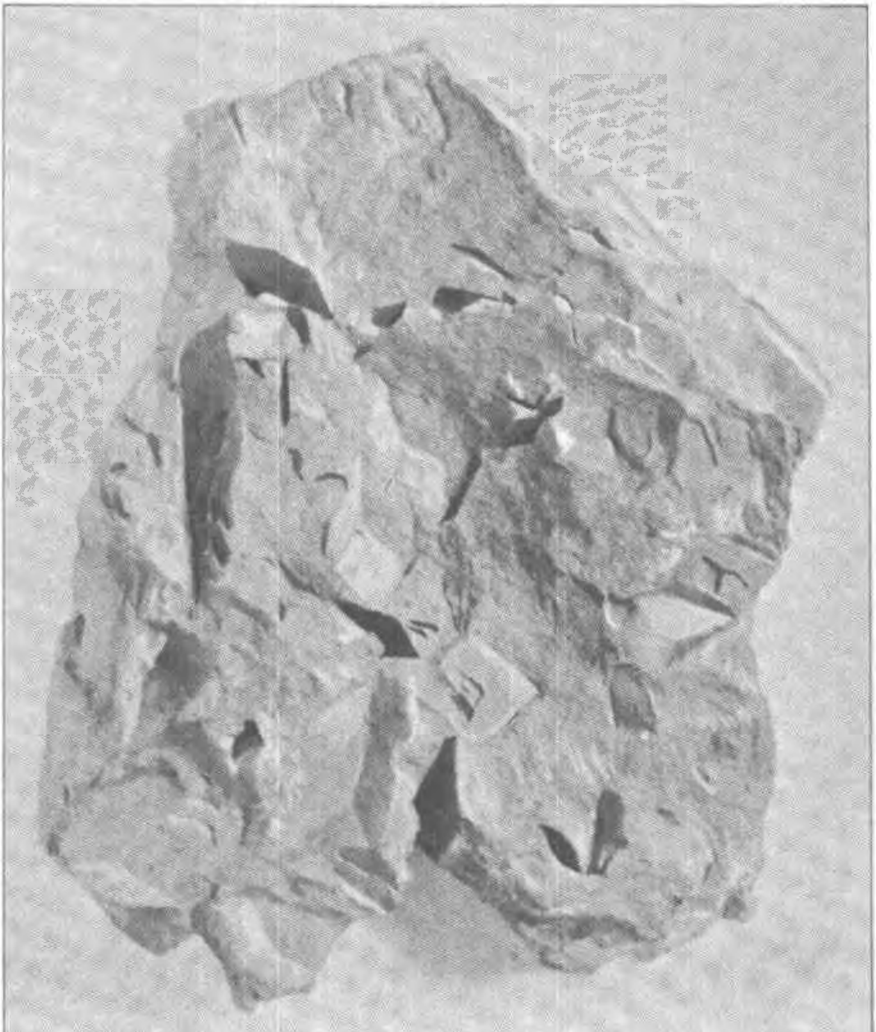

Photograph by U. S. National Museum

GLAUBERITE CRYSTAL-CAVITIES IN TRIASSIC SHALE, STEINSBURG, BUCKS CO., PA. (×½)

PLATE III

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GLAUBERITE CRYSTAL-CAVITIES IN THE TRIASSIC ROCKS OF EASTERN PENNSYLVANIA[1]

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AT A number of places in eastern Pennsylvania the Triassic rocks contain numerous cavities, or calcite pseudomorphs, which show by their angular form that they were originally occupied by a crystalline mineral. Study of specimens of these has demonstrated the original mineral to have been glauberite, $Na_2Ca(SO_4)_2$. Similar pseudomorphs in shale from Princeton, and cavities in the zeolite deposits of the First Watchung Mountain, in New Jersey, are believed to represent the same mineral. A preliminary announcement of these conclusions has already been made,[2] but in the present paper the Pennsylvania occurrences are described in greater detail.

Altho these crystal cavities occur at a number of widely separated localities, they are particularly well developed one mile south of Steinsburg, Bucks County. The rocks here exposed comprise gray, green, and dull red shale and argillaceous sandstone. To some extent in all of these rock types, but in especial abundance in the dull red sandy beds, there appear numerous cavities, singly and in groups, and lozenge-shaped in cross section. They vary in outline from tabular to elongated-pyramidal, the pyramid edge attaining a maximum length of five centimeters, and show no definite orientation in the bed. A photograph of a specimen[3] of the rock containing a number of these cavities is shown in the frontispiece, Plate III.

The shape of the cavities shows clearly that they are molds of crystals of some soluble salt, which must have crystallized in

[1] Published by permission of the Secretary of the Smithsonian Institution.

[2] *J. Wash. Acad. Sci.*, **6**, 181–184, 1916.

[3] U. S. National Museum Cat. No. 92931.

the mud while it was still soft, but remained intact until it had become thoroly hardened. While this locality was discovered in 1909 by Mr. George W. Geist of Philadelphia, and the writer (then instructor in mineralogy at Lehigh University, South Bethlehem, Pa.), no opportunity to study the specimens critically was found until 1915. During the summer of that year, however, an effort was made to determine the nature of the mineral from the shape of the cavities, as part of the writer's research work at the National Museum.

Some of the cavities were broken open lengthwise, and plaster casts of them prepared. Comparison of these with various saline minerals showed that the original mineral was undoubtedly glauberite, the double sulfate of sodium and calcium, $Na_2Ca(SO_4)_2$. The distribution of faces indicates the mineral to have been monoclinic, with forms that may be described as a basal pinacoid, a pyramid with strongly striated and often convex or concave surfaces, and a prism. The angles, measured with a contact goniometer, compared with those of natural crystals, are given in Table I.

TABLE I. ANGLES MEASURED ON CASTS AND NATURAL CRYSTALS OF GLAUBERITE

Forms	*Casts of cavities in shale, Steinsburg, Pa.*	*Glauberite crystals, California*	*Forms and theoretical angles*	
			001∧334	36°41′
Base∧pyramid	36–43°	38–43°	001∧445	38° 7′
			001∧111	43° 2′
			334∧334	55° 2′
Pyramid∧pyramid	54–64°	57–64°	445∧445	57° 2′
			111∧111	63°42′
Prism∧prism	96–98°	97°	110∧110	96°58′

The variations in the above angles are due to the curvature of the faces, which renders exact measurement impossible. The pyramid faces are actually composed of three forms, in oscillatory combination with one another, as shown by the striations, and only in rare cases does one of these forms stand out individually. The agreement between the angles of the casts and natural crystals is, however, noteworthy. And the similarity extends further: the habit, mode of intergrowth, and striations of these casts are like those of the natural glauberite from California, as brought out in Figure 1, the three in the upper row being plaster casts of cavities in the specimen, while the three in the second row are natural crystals.[4] In both casts and crystals the base is dominant, a pyramid well developed, and the prism small. From the base of both occasionally project smaller crystals intergrown with the larger ones in sub-parallel position. And, most striking of all, the pyramid faces of both are horizontally striated by oscillatory combination with the base or another pyramid. The identity of the mineral which formed the cavities with glauberite may therefore be regarded as established.[5]

In addition to the typical crystal forms shown by the majority of the cavities, as above described, certain peculiar types of crystals are occasionally found. The most important of these is the long-pyramidal type, a good example of which is illustrated in the center of the bottom row on Figure 1.[6] Altho crystals of this habit are not known to occur at the California locality, they have been reported from other places. Groth[7] mentioned that the reddish colored glauberite from Iquique, Peru, in the Strassburg mineral collection, is in very long slender prisms after the pyramid (111). Dana[8] stated that the mineral may be prismatic by extension of the same form. And among the duplicate minerals in the National Museum collection there was found a single crystal, labeled Clear Lake (?), California (but without catalog number or any statement as to its history), which has the pyramid faces greatly elongated and tapering.

In most cases the crystal cavities have sharp edges, indicating that no solution took place before the hardening of the enclosing mud. In certain layers of the rock, however, the glauberite had begun to dissolve before the mud surrounded it, the faces being deeply corroded. A cast of one of these[9] is figured in the lower left hand corner of Figure 1.

In another road cut, about one half mile southwest of the one yielding all of the cavities thus far described, which may be known

[4] U. S. N. M. Cat. Nos. 47556 and 84006.

[5] When the preliminary announcement (*loc. cit*, note 2) appeared, Prof. J. Volney Lewis informed the writer that he had been studying for some time similar cavities in Triassic shale from the Gettysburg, Pa., region, collected by Mr. George W. Stose, and had decided that they represented glauberite. The fact that we reached the same conclusion independently may be regarded as final proof of its validity.

[6] U. S. N. M. Cat. No. 92962.

[7] *Min. Samml. Univ. Strassburg*, 155, 1878.

[8] *System of Mineralogy*, Ed. 6, 899, 1892.

[9] U. S. N. M. Cat. No. 92962.

as the Spinnerstown locality, since it lies one half mile northeast from that place, the strata contain instead of cavities numerous pseudomorphs of calcite after glauberite. The crystal outlines are usually somewhat less distinct than those of the cavities, yet there can be no question that they represent the same mineral, as will be seen from the photograph of one of them[10], in the lower right hand corner of Figure 1. The calcite is minutely granular, showing no cleavage faces to the naked eye, although in thin section under the microscope it has all the properties of calcite. Its pseudomorphic character is proved by this structure, for if it had filled an open cavity it would probably have been much more coarsely crystalline.

Similar cavities and calcite pseudomorphs, tho mostly less well developed, are found at a large number of localities in the same general region. At times they are large and rounded, again sharp but very minute and scattered thru the rock in enormous number. They appear to occur thruout the 10,000 feet of beds in the Brunswick formation, altho if anything they are more abundant in the upper portion.

In the Lockatong or Gwynedd formation which underlies the Brunswick, differing in the greater hardness and darker colors of the beds, Mr. A. C. Hawkins [11] noted the occurrence of pseudomorphs of calcite and analcite after a mineral which he did not identify, but which was later suggested by the writer to be glauberite. A visit to the localities described by Mr. Hawkins,—quarries in the eastern part of Princeton, New Jersey, and one near Mt. Eyre, southeast of Dolington, Pa.,—in company with Dr. Schaller of the U. S. Geological Survey, yielded abundant evidence of the correctness of this view, in that the pseudomorphs showed the same forms as those in the Brunswick formation, differing only in their more elongated habit; crystals as much as 10 cm. long but only 2 mm. in diameter were noted. The waters from which the Lockatong beds were deposited apparently contained considerable silica (colloidal) and this may possibly have been the cause of the unusual crystal habit. The Stockton or Norristown formation, which underlies the Lockatong, and is the lowest member of the Triassic of the region, has not been observed to contain glauberite, but it consists largely of feldspathic sandstone and conglomerate, and was probably not formed under conditions favorable to the crystallization of saline minerals.

[10] U. S. N. M. Cat. No. 92962.

[11] *Ann. N. Y. Acad. Sci.*, **23**, 163, 1914.

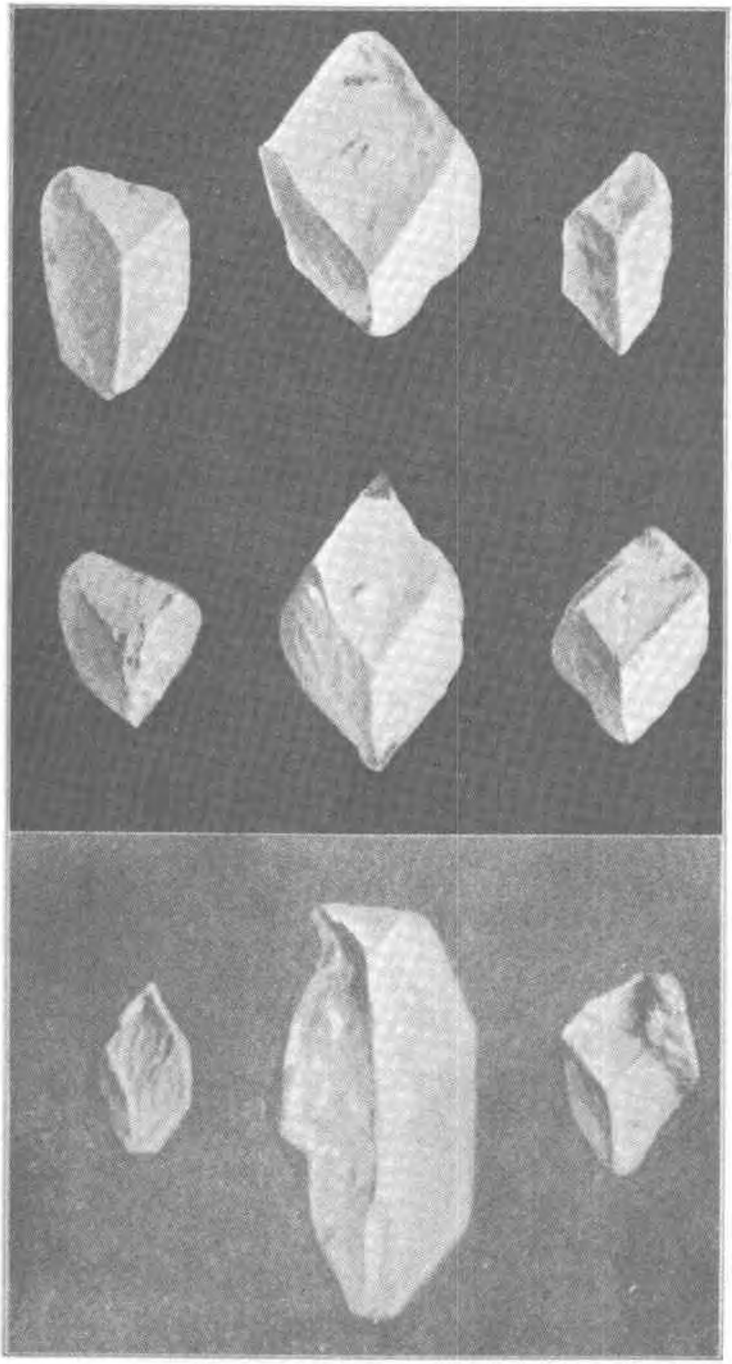

FIGURE 1.—GLAUBERITE CASTS, CRYSTALS AND PSEUDOMORPH

The Triassic or Newark of eastern North America exhibits many peculiar phenomena which, though long unexplained, are now being interpreted by geologists as the results of the continental, and especially the fluviatile, deposition of the strata under a climate of greater or less aridity.[12] That the waters in which they were laid down were shallow and repeatedly became dried up—conditions typical of river flood-plains—is shown by the abundance of ripple marks and mud cracks; by the bright red color of most of the rocks, indicative of thoro aëration; by the frequent presence of calcite, in nodules or scattered grains; and by various other lines of evidence. Here and there thruout the red beds occur lens-shaped bodies of green, gray, or black rocks, owing their colors to the presence of carbon and of ferrous-iron minerals. These beds were evidently formed under conditions of less thoro aëration, and were no doubt deposited in swamps, ponds, or lakes. The glauberite is usually found in or near these darker colored beds.

The genesis of the Triassic glauberite is accordingly interpreted to have been as follows: When the Triassic rivers spread over their floodplains, forming lakes, puddles, or swamps, from which the water rapidly evaporated, any saline constituents present in the water would of course crystallize out. The waters of many existing rivers are characterized by the presence of the ions of sulfuric acid, calcium, and sodium, and the same may well have been true of those of Triassic times; these constituents would crystallize together as glauberite. When a small body of water was formed, evaporation would occur with especial rapidity, and numerous small crystals would result; when a large lake developed, so that crystallization could take place more gradually, the crystals would be fewer in number, but larger in size. When mud surrounded the crystals and protected them from re-solution, their form would be accurately preserved; when partial solution could take place owing to dilution cavernous faces would be produced. All of the features of the occurrences above described can thus be readily explained.

Whether the calcite occasionally found as pseudomorphs after the glauberite crystals was deposited from the same Triassic lakes, or whether it represents the result of the action of ground waters carrying carbon dioxide upon the glauberite long after the

[12] See, for instance, Pirsson and Schuchert, *Text-book of Geology*, 814, 1915.

hardening of the beds into rock can not be definitely decided from the evidence at hand, but the latter explanation seems the more reasonable. The widespread occurrence of glauberite cavities (and pseudomorphs) shows that conditions of aridity must have prevailed thruout the deposition of the greater part of the Triassic beds of this region.

It may be noted in passing that halite rather than glauberite is represented by crystal cavities and pseudomorphs in the New England Triassic. Thus at Wilbraham and Holyoke, Massachusetts, the sediments contain cubical cavities and impressions of skeleton cubes, originally occupied by halite.[13] At West Springfield occur calcite replacements of skeleton crystals which have been regarded by various writers as such widely different minerals as chiastolite, spinel, and octahedrite, but were shown by Professor Emerson to be pseudomorphs after halite.[14] Evidently the waters of Triassic rivers in that region differed in composition from those in what is now Pennsylvania and New Jersey; or perhaps the ocean was nearer, and sodium chloride was carried inland as spray. At any rate, aridity sufficient to develop saline minerals also characterized Triassic climate there.

The cavities in the zeolite deposits of the First Watchung Mountain, New Jersey, will be described in detail by Dr. W. T. Schaller of the U. S. Geological Survey, and nothing will here be added to what has been stated in the preliminary paper cited above. The evidence that these cavities, too, represent glauberite seems convincing.

[13] Emerson, *Bull. U. S. Geol. Survey*, **126**, 144–145, 1895.

[14] *Ibid.*, 144–147; also *Bull. Geol. Soc. Amer.*, **6**, 473, 1894.