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SAND-CALCITE CRYSTALS FROM MONTEREY COUNTY, CALIFORNIA*

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AND

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I. Occurrence by R. D. Reed

Sand crystals of such minerals as calcite, gypsum, and barite have been found in widely scattered localities, many of them in the more arid parts of the world. They have given rise to several interesting mineralogical and geological investigations, to some of which references[1] are given below. The purpose of the present paper is to describe a new California occurrence of sand-calcite crystals of peculiar crystallographic development.

These crystals occur in the Cholame Hills, the highest part of a well-known mesa which lies between the San Andreas Fault and the Salinas River in southeastern Monterey County. The marginal portions of the mesa are of fairly complex structure, one of the most complicated portions being the Cholame Hills. A brief account of the geology, with a reconnaissance map, has been published by the United States Geological Survey.[2]

The crystals occur in a limited portion of an outcrop of clean, white, poorly cemented sand of Santa Margarita (upper Miocene) age, near a fault contact with Pliocene strata, perhaps of much

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[1] B. Doss, Ueber sandhaltige Gypskrystalle vom Bogdo-Berge in der Astrachanschen Steppe, *Z.deut. geol.Ges.*, **49,** 143-151, 1897. (References to other occurrences, *op. cit.*, 150, 151.) E. H. Barbour, Sand crystals and their relation to certain concretionary forms, *Bull. Geol. Soc. Am.*, **12,** 165-172, 1901. H. W. Nichols, New forms of concretions, *Field Columbian Museum Pub.*, geol. ser. **3,** 25-54, 1906. J. E. Pogue, On sand-barites from Kharga, Egypt, *Proc. U. S. National Museum*, **38,** 17-19, 1910. J. Walther, Das Gesetz der Wüstenbildung, vierte Auflage, 72-75, Abb. 58-60, *Leipzig*, **1924**. H. R. Wanless, Notes on sand-calcite from South Dakota, *Am. Mineral.*, **7,** 83-86, 1922.

[2] W. A. English, Geology and oil prospects of the Salinas Valley-Parkfield area, California, *U. S. Geol. Survey Bull.*, **691-H**, 1918.

later age. They show no close relation either to bedding planes or joint cracks in the sand. No outcrops of limestone, either in the older or younger formation, have been seen in this vicinity, but there are, scattered over the surface above the Pliocene strata—which are not well exposed—many fragments of hard massive limestone of a peculiar kind. These fragments are very similar to those furnished by thin beds of limestone widely distributed in the Paso Robles formation (non-marine Pliocene) in other parts of the same general area. Their abundance in this part of the Cholame Hills suggests that the strata in contact with the Santa Margarita formation may be Paso Robles, and not marine Pliocene as the map of the Geological Survey indicates. The fact that the contact seems clearly to be a fault tends to confirm this idea. Only a detailed examination of the general area can settle the matter.

Rough chemical determinations show that the proportion of sand to calcite in the crystals is about 65 to 35. This agrees well with an average of 63 per cent sand in the Great Plains crystals studied by Barbour.[3] The sand of the crystals is similar to that of the matrix in which they occur. It is coarse and composed chiefly of angular quartz grains. Feldspar is much less common than in most other Tertiary sandstones of California. Heavy minerals are also present in small amount, the commonest species being titanite.

The only isolated sand-calcite crystals and groups of crystals and concretions that have been found are in an area a hundred yards long and a few yards wide, in section 14, T. 23 S., R. 13 E. A few miles west of this locality, however, in the Narrows, section 21, T. 23 S., R. 13 E., the Santa Margarita sandstone crops out again, here overlain by several hundred feet of diatomaceous shale, as well as by the marine and non-marine strata of the Pliocene. Instead of white, uncemented sand, however, the Santa Margarita formation is here a resistant calcareous sandstone with a peculiar nodular appearance on weathered surfaces. The calcite of the nodules, as shown by the cleavage planes on a fractured surface, is in large anhedral crystals, but no euhedral crystals or concretions were seen.

The origin of sand-calcite crystals is not always entirely clear. Walther groups them with the products of insolation and evaporation in desert areas. "Auch die bekannten Sand-Kalkspate von

[3] E. H. Barbour, *op. cit.*, p. 170.

Fontainebleau gehören hierher."[4] The conditions at Fontainebleau are described in more detail in a suggestive passage by Jukes.[5] The sand, he says,

"is covered in places by beds of freshwater limestone called the Calcaire de Beauce. Water containing carbonate of lime in solution percolates through the sand and deposits the lime, binding the sand either into globular concretions, or even into rhombohedral crystals, such as carbonate of lime ordinarily forms. Besides these smaller concretions, other large parts of the sand have been compacted together into a very hard gritstone, which is extensively used as a paving stone."

In the Wyoming locality Barbour notes the same transition "from the solitary crystals to the concretions, compound concretions or pipes, to the compound pipes and solid rock," but says

Fig. 1. Sand-Calcite Twin-Crystal from Cholame Hills, Monterey Co., California.

little about the source of the calcium carbonate and the conditions of its precipitation. In the Cholame Hills the complex structure makes it impossible to discuss these problems profitably without more work than has yet been devoted to them. In any case the geologic significance of these concretions, as stages toward the development of a completely cemented stratum, is sufficiently clear.

[4] J. Walther, *op. cit.*, p. 75.

[5] J. Beete Jukes, The Student's Manual of Geology, third edition. Sir. A. Geikie, *Edinburgh*, **1872**, Chapter XV.

II. Crystallography by Austin F. Rogers

The specimens collected by Dr. Reed, and presented by him to Stanford University, vary from rough concretions which approach a spherical form to well-formed crystals such as those illustrated in Fig. 1. Most of the specimens show a confused mass of projecting crystals without any apparent relation to one another. An occasional simple crystal was noted. The most interesting of all the specimens are those represented by Fig. 1. For this photograph I am indebted to my colleague, Professor F. G. Tickell. At first glance these seem to be penetration twins of two hemimorphic crystals but a closer study proves them to be penetration cyclic twins made up of four individuals. The only form present is the negative or inverse rhombohedron $f\{02\bar{2}1\}$, the edges and faces of which are somewhat rounded, partly by wear and partly by crystal growth. Surrounding the central crystal, the lateral edges of which show in the photograph, are three other individuals each in twinning position. Fig. 2 shows a plan and elevation of a twin-crystal in ideal development. The photograph of Fig. 1 was taken in the same position as the elevation of Fig. 2. The relation of two individuals of the twin is shown in the right-hand drawing of Fig. 2. The twin-plane is the form $\{01\bar{1}2\}$, but the composition plane is a plane at right angles to $\{01\bar{1}2\}$, which plane is not a crystallographically possible face.

The angle $(02\bar{2}1 : \underline{02\bar{2}1})$ was measured by means of a Penfield contact goniometer from a wax impression of a part of the photographed specimen of Fig. 1 with the following results: Limits 72°30′-74°0′. Average of 10 values = 73°8′. Calculated value = 73°44′. 2(63°7′-26°15′) = 73°44′. On another specimen, the edge and arm of the goniometer were held in the line of sight of the two faces mentioned and the following results were obtained: Limits 72°30′-75°0′. Average of 10 values = 73°32′. Calculated value = 73°44′.

In most twin-crystals the two individuals are on opposite sides of the twin-plane but occasionally, as has been pointed out by Spencer,[6] the two individuals may be on the same side of the twin-plane. Such is the case in the sand-calcites here described. In the abstract[7] of this paper it was stated that the twin-plane is the positive or direct rhombohedron, $\{20\bar{2}1\}$. This twin-law for

[6] *Mineralog. Mag.*, **18,** 82, 1916.
[7] *Am. Mineral.*, **10,** 68, 1925.

calcite was described by Lacroix[8] on crystals from Saint-Julien-de-Valgalgues, France. In the case of $\{20\bar{2}1\}$ as a twin-plane the angle $02\bar{2}1 : \underline{02\bar{2}1}$ is 72°28′ instead of 73°44′. 180°-2[180°-2(63°7′)] = 72°28′. The difference of 1°16′ is practically within the limits of error for rough crystals such as these sand-calcite crystals. The

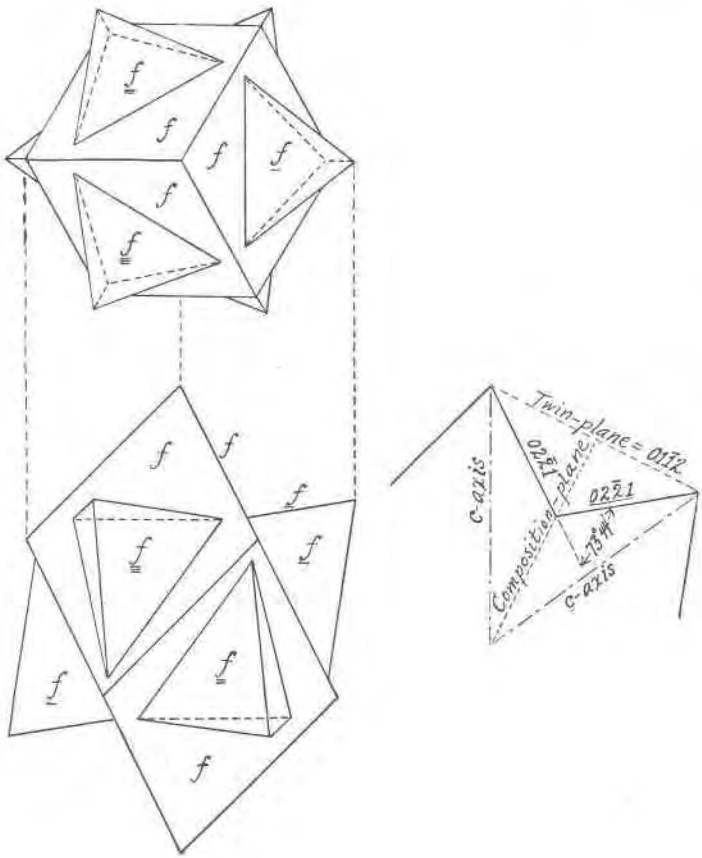

Fig. 2. Plan and Front Elevation of Sand-Calcite Twin-Crystal from Cholame Hills, Monterey Co., California. ($f\{(02\bar{2}1\}$, Twin-plane = $\{0\bar{1}12\}$).

$(10\bar{1}1)$ cleavage truncations of the polar edges of the central crystal and two other individuals of the sand-calcite crystals are in the same plane, since they reflect light at the same time. This

[8] Minéralogie de la France, **3**, 563-4, 1909.

observation is proof that $\{01\bar{1}2\}$ and not $\{20\bar{2}1\}$ is the twin-plane, for only in the former case are cleavages of two individuals parallel.[9]

Calcite twins of this type have been described from Elba,[10] Eisenerz[11] (Styria), Hüttenberg[12] (Carinthia), Rancie[13] (France), and Velmanya[13] (France). None of these twin-crystals, however, are sand-calcite crystals.

The form present on the sand-calcite crystals from Fontainebleau (France) and Vienna is the negative rhombohedron $f\{02\bar{2}1\}$, but as far as known they are not twinned.

At the only previously known American locality for sand-calcite crystals,[14] Rattlesnake Butte, Jackson County, South Dakota, the dominant form on the crystals is the hexagonal bipyramid, $\gamma\{8.8.\overline{16}.3\}$, which is one of the characteristic forms of calcite.

The Cholame Hills specimens here described, then, are apparently the only twin-crystals of sand-calcite on record.

[9] It seems probable that $\{01\bar{1}2\}$, and not $\{20\bar{2}1\}$, is the twin-plane in the calcite crystals from Saint-Julien-de-Valgalques described by Lacroix. If this is true, then only the four following twin-laws are exemplified in calcite: $c\{0001\}$, $e\{01\bar{1}2\}$, $r\{10\bar{1}1\}$, and $f\{02\bar{2}1\}$.

[10] Rath, see Goldschmidt, Atlas der Krystallformen, *Heidelberg*, 1913, **2**, pl. 77, fig. 1395.

[11] Vrba, *ibid.*, pl. 79, fig. 1424.

[12] Rath, *ibid.*, pl. 86, figs. 1510-1511.

[13] Duffour, *Bull. Soc. Fran. de Min.*, **46,** 95-101, 1923.

[14] Penfield and Ford. *Amer. J. Sci.* [4], **9**, 352-354, 1900.

A PECULIAR MANGANIFEROUS SERPENTINE FROM FRANKLIN FURNACE[1]

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and

Esper S. Larsfn, *Harvard University*

Some two years ago a specimen of a peculiar red-brown mineral was sent to Professor Larsen for identification by Col. Roebling. Although this material superficially resembled garnet its optical properties were such that it could not be that mineral and, at the request of Professor Larsen, Mr. Shannon agreed to analyze the mineral and Colonel Roebling gave his permission for the removal of enough material from the specimen for the analysis. The specimen, following the preliminary microscopic examination, was returned to Col. Roebling who, somewhat later sent it again to

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