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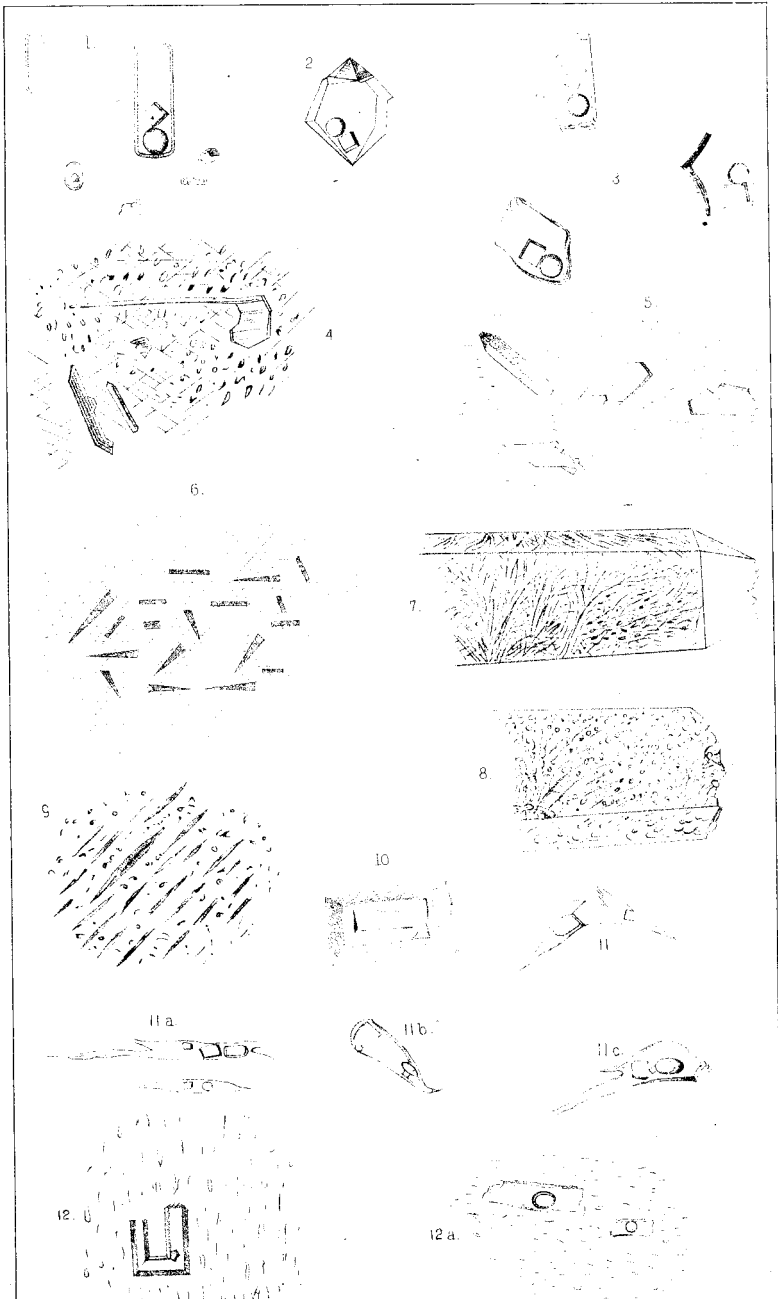
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On the Cover

This outstanding design in diamond jewelry, by Coleman E. Adler & Sons, Inc., New Orleans, received an award in Diamonds, U.S.A. Awards sponsored by N. W. Ayer & Son, Inc. The necklace of brilliantly fashioned baguettes in various sizes, accented with rounds, has a stunning pear-shaped diamond pointing to the last diamond in the streamer.

Photo courtesy
Dorothy Dignam
N. W. Ayer & Son, Inc.
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Microscopic Crystals & Cavities in Gems

Further Notes on "Inclusions" in Gemstones, Etc.

by

ISAAC LEA, LL.D., MAY, 1876

Note: The following article is a verbatim reprint of one of three papers written for the Proceedings of the Academy of Natural Sciences of Philadelphia by Isaac Lea. (Reprints of two of these papers appeared in the Fall issue of GEMS & GEMOLOGY). These papers probably represent the first work done in this country on gemstone inclusions. The earliest paper carries the date of February 16, 1869. The Isaac Lea gem collection is at the United States National Museum, Washington, D.C.

The articles were made available for readers of GEMS & GEMOLOGY through the courtesy of George Switzer, Ph.D., Associate Curator, Division of Mineralogy and Petrology, Smithsonian Institution.

In a communication on microscopic crystals contained in *gems*, which the Academy did me the favor to publish in its Proceedings¹ a few years since, I gave some figures of these crystals which I have frequently since verified. I then observed that, beside these *inter-crystalline forms*, there were in most *gems*, *cavities* frequently so numerous that they amounted to tens of thousands.

Since the period of the publication of my paper, I have made very large additions to

my cabinet of *gems*, and particularly those of the *Corundum* group, *Sapphires*, *Rubies*, and the so-called *Oriental Topaz*, *Oriental Amethyst*, *Asteria*, etc. In the numerous fine blue *Sapphires* of my collection, I have rarely explored one without finding numerous cavities, and ordinarily also finding the beautiful microscopic acicular crystals, which, when the specimen is cut *cabochon*, cause the three bands, and these by crossing form the star in *Asteria*. The cuneate microscopic crystals are also quite common.

Cavities, with or without the fluids, are so frequent in *crystals*, from the soft *Calcite* to the hard *Corundum*, that little may be said as to their occurrence, as they are so common.

Cavities in quartz crystals inclosing fluids have been observed by the older mineralogists, but the kind of fluid, and gas or air, was not ascertained by them. Sir Humphry Davy, in 1822,² investigated the contents of these cavities, and found them generally pure water. The gas bubbles were sometimes found to be "*azote*." Sir David Brewster, in 1823,³ published a memoir of great research

¹ Feb. and May, 1869.

² Trans. Roy. Soc. Ed., 1823.

³ Phil. Trans., 1822.

and value. He first had his attention called to the examination of fluid in cavities by the explosion of a crystal of *Topaz* when heating it. He found cavities and air bubbles in nearly twenty different substances, and these inclusions were carefully examined by him. In some of these cavities he observed two fluids¹ and crystals, and these are figured in his plates. Subsequently, Mr. Sorby published a long and admirable paper² on *Fluid cavities and crystals* in minerals, with numerous and interesting figures. He considered that the cubic crystals were probably *Chloride of Sodium*. In his investigation he proved, by forming artificial crystals, that, in a natural state, the fluid cavities, with their "inclusions," must have been formed by aqueo-igneous forces. He gives a figure of fluid in mica, but I have never seen any in that mineral, although many hundreds have passed under my microscope in looking after crystals of *Magnetite*, etc. Mr. Sorby also published a paper on cavities in quartz in the *Phil. Mag.*, vol. xv. p. 153; also with Mr. Butler in *Proc. Roy. Soc. London*, vol. xvii. p. 299. Kirkel on *Microscopic Minerals*, *Neues Jahrbuch*, 1870, p. 80, mentions bubbles and cubic crystals in quartz. He found iron glance and fluid in *Elaeolite* = *Nephelise*. In *Emery*, from Naxos, he found fluid in cavities.

In 1872, *Proc. Roy. Soc. Edin.*, p. 126, Mr. Sang published an account of water in cavities of *Calcite*.

Very recently, Prof. Hartley, King's College, London, has published a very able paper on the subject of the fluid in quartz, etc.³ He says that Simmler in 1858, offering an interpretation of Brewster's observations, concluded that the expansible liquid was carbon dioxide. Professor Hartley states that in many cases the liquid in quartz is water but that in some cases he found the two fluids,

¹ These two fluids, Prof. Dana without any analysis has called *Brewsterinite* and *Cryptolinite*.

² *Journ. Geol. Soc.*, vol. xiv., 1858, *Microstructure of crystals*.

³ *Journ. of the Chem. Soc.*, London, Feb. 1876.

⁴ Specimen in the collection of the late Dr. Chilton of New York.

and his very satisfactory and careful experiments show conclusively that the most volatile of the two fluids is carbonic dioxide. He found in every experiment, that the fluid disappeared when exposed to 31° C., and reappeared on cooling. Prof. Hartley accords with Mr. Sorby in his reasoning that "at the time of its assuming the solid state, the solution endured a high temperature."

Calcite has been found to contain nearly a quart of this fluid,⁴ but it is not as common to be found in small cavities as it is in quartz.

Fluorite, — Cavities in this mineral are rarely found, but they are sometimes seen with fluid and air bubbles.

Apatite, — I have never observed cavities in this mineral, but I have not given it much attention in microscopic examinations.

Feldspar Group, — In a former paper,⁵ I gave the result of the examination of many specimens of various species. Since then I have examined numerous specimens of *Labradorite*, and found no cavities, but the black crystals were very numerous. In the *Moonstone* of this country, I have not observed cavities or crystals, but in two specimens, out of about one hundred from Ceylon, I have seen a series of very regular quadrate cavities or crystals which do not appear to have any fluid. Fig. 10, Pl. 2.

Tourmaline, — This interesting mineral is found beautifully crystallized and of almost all colors, white, brown, green, red, black, etc. The finest are found at Mount Mica, near Paris, Maine.⁶ Some of these specimens have small internal elongate crystals, which are terminated. A red specimen (*Rubellite*) in my collection has many irregular cavities. One green one from Ceylon has cavities with fluid, and another has very minute black acicular crystals in one direction. In brown crystals from Lower Dianburg, Corinthia, there are rough objects in the interior, evidently another mineral inclosed, which do not require the microscope to detect them.

⁵ *Prod. Acad. Nat. Sci.*, May 11, 1869.

⁶ Dr. Hamlin has published a beautiful little work on the *Tourmaline*, with illustrations.

Cyanite. — Of the white and the blue varieties I have not observed any well-defined cavities or crystals, but in the gray-bladed *Cyanite*, found at Cope's Mills, near West Chester, Pennsylvania, there are always, I believe, small black masses which do not take a regular form, but are usually elongate. These may easily be detected by splitting a crystal along its eminent cleavage, and examining the cleavage face with a lens of small power, but a higher power is preferable.

Quartz takes upon itself many colors. In it are found cavities in very great numbers, particularly in the clear fine crystals. Those which exist in such an abundance in Herkimer County, New York, and which are so limpid, and finely and doubly terminated, are sometimes furnished with thousands of cavities, even in small specimens, and these are of many various forms, frequently containing fluid. In some cases the fluid may be seen to move by the unaided eye. In these Herkimer crystals, carbon in the form of *Anthracite* is of very common occurrence, and in one of my specimens a small portion moves in the fluid of a cavity. These cavities often exist in an entire sheet, almost across the prism of a crystal.¹ In *smoky quartz*,² these cavities are much rarer, as also in *Amethyst and wine-color and green quartz*. The *Amethyst* is frequently penetrated with crystals of *Rutile*, and these are often very large, sometimes 1 to 4 inches long. The Chester county specimens usually have numerous curved filamentous crystals, easily detected with a common lens. In Way's Feldspar Quarry, near Dixon's, Delaware, there is a very peculiar form of *quartz* which is nearly transparent, but somewhat clouded. The fragments of all sizes, from that of a pin's head to that of a small walnut, are inclosed in a mass of *Deweylite*. These fractured pieces are of indefinite forms. They are evidently cryptocrystalline, and look as if they may have been heated and suddenly cooled, and thus fractured. When these pieces are subjected to a high power, there may be detected in them very minute *oval cavities* in great numbers,

and the major axes usually placed in one direction. I have never seen cavities in *milky quartz* or *blue quartz*. Sir David Brewster found many cavities in rock crystal from Quebec with "water and mineral oil."

Topaz. — In the various beautiful crystals which this mineral presents, there are frequently found cavities with fluid, and sometimes in this fluid may be seen the cuboid crystals described by Sir David Brewster. He found a single fluid in some cavities, and in other two fluids with "air bubbles." He says the fluid does not expand with heat. The Saxony transparent white crystals sometimes have cavities, as well as those of pale wine-color. The Brazilian gold-yellow specimens have these cavities very frequently. The clear pinkish are more free from them. I have never observed any microscopic acicular crystals in *Topaz*.

Emerald, Aquamarine, and Beryl. — Constitutionally the same — differ very much in regard to their possession of cavities and their commercial value. So far as I have been able to examine fine specimens of *Emerald*, it is rare to see one without cavities. One which I have, of very fine color, has many cavities of various forms, in which are included a fluid enveloping generally two perfect cubic crystals of an unknown mineral. In all cases in this specimen, the second crystal is much the smaller. Fig. 11, Pl. 2.

Ir Aquamarine, cavities are not frequent, and in *Beryl* I have detected them only in a specimen from Unionville, Penn. Fig. 12, 12a, Pl. 2. In this there is a biangular cavity with a small cubic crystal at an inner angle. Throughout the mass there are small suboval cavities.

Garnet. — As a precious stone this is by no means rare, but it is lustrous and of fine color. Cavities and microscopic crystals are

¹ Sorby, Journ. Geol. Soc., 1858, found many cavities, and thinks that the cubic crystals inclosed are probably chloride of sodium, as mentioned above.

² The smoky quartz of Pike's Peak has hexagonal spangles, which may be mica.

³ Trans. Roy. Soc. Ed., vol. x.

very common in this gem.¹ The cavities are usually irregular and rough, and never to my knowledge have fluid. On a polished surface of a piece of garnet from North Carolina, nearly an inch long, the reflection of these crystals covered the whole surface with prismatic colors.

Cinnamon Stone. — This beautiful variety of *garnet*, from Ceylon, as far as I have been able to observe it, and I have some twenty cut specimens, and numerous rolled pieces, has irregular cavities and some crystals, as I have stated in a former paper.

Zircon. — With its high refractory power, this is used frequently as a *gem*, and sometimes sold as a diamond when white and perfectly transparent. One of the numerous specimens which I have examined has cavities² and microscopic crystals, and a specimen from Ceylon has remarkable dark brown, elongate, fusiform spots, with numerous dotted ones intervening. Fig. 9, Pl. 2.

Chrysoberyl. — The few specimens I have of this beautiful *gem* have neither cavities nor microscopic crystals, but Brewster observed "strata of cavities and both the fluids."

Chrysolite = *Olivine*. — In some of my specimens I have observed small cavities with fluid. Brewster met with them containing "fluid and bubbles of air."

Spinel. — This *gem* occurs of several colors. The *Spinel-ruby*, so called, sometimes is very close in color to the true *Ruby*, but it has not by any means the depth nor brilliancy of the true *Ruby*. In a pale-green specimen of great beauty which I have received recently from Ceylon, I have not been able to detect cavities or crystals. In my former papers I have expressed uncertainty in this matter.³

Iolite. — This *gem* is inferior in hardness, color, and specific gravity to *Sapphire*, but is valued for its peculiar change of color, being dichroic. One of my specimens is without inclusions. The other is filled with blue four-

sided prismatic crystals, which are long, and inclosed in a nearly white subtransparent mass. These crystals are sometimes broken and their parts prolonged in the mass, and they are all lying in nearly the same direction.

Turquoise, with its peculiar and agreeable blue, is never transparent, and neither cavities nor microscopic crystals are found in it.

Opal. — This exquisite gem, which displays such brilliant colors, is very highly valued. It is but little harder than glass, and is indeed considered as volcanic glass. Its remarkable flashes of color are attributed to fissures, in accordance with the theory of Newton's colored rings. I have never been able to detect either cavities or minute crystals in this beautiful gem — except in two cases. One of my specimens has a brown, terminated crystal, a six-sided prism of an unknown substance, about one-fifth of an inch long, and terminated by a single oblique plane; the other has several smaller ones.

Lapis-lazuli. — This was used by the ancients as a favorite *gem*, but it is not now valued as such. I have not been able to detect cavities or minute crystals in any specimen in my possession.

Corundum. — This very interesting mineral, when in perfect transparent crystals, is highly valued as a *gem*, under the name of *Sapphire*, *Ruby*, etc., according to color. When yellow, it is called *Oriental Topaz*; when purple, *Oriental Amethyst*. When purely white it is sometimes sold as a *Diamond*. In this country we have two localities only of *Corundum* where any large quantity has been found, that of Chester County, Pennsylvania, and Franklin County, North Carolina. From the mines in Chester County, several hundred tons have been taken, but no transparent crystals. Some opaque ones are bluish and some pinkish. The North Carolina locality has produced some very large crystals, and numerous small ones. Of the latter there have been found many quite pure and transparent, and these are sometimes

¹ Proc. Acad. Nat. Sci., Feb. and May, 1869.

² In a specimen in Dr. Leidy's fine cabinet there are anastomosing cavities.

³ Proc. Acad. Nat. Sci., Feb. and May, 1869.

blue and sometimes red. But none of them yet found are of value as *gems*. The fine *Sapphires* and *Rubies* are chiefly from Ceylon, and they form some of the most beautiful objects in nature. I have many of these in the form of worn pebbles, and some in fine hexagonal form, as well as hundreds of cut specimens. I have examined carefully more than one thousand specimens, with a view to discover whatever "inclusions" they might possess. In a communication to the Academy,¹ I described and figured some microscopic crystals in these and other *gems*. Since then I have added a very large number to my collection, and among these several hundred large and small transparent crystals. In a careful microscopic examination of these I found a large number which contain cavities and minute crystals, the former sometimes scattered irregularly through the mass, and sometimes forming a sheet or film. These cavities are of all forms, but usually sub-elliptical; sometimes tubular, and these tubes frequently anastomose in a very beautiful manner. These cavities are so numerous that they frequently give a cloudiness to the specimen which is less valuable as a *gem*, but most interesting in a scientific point of view. In some specimens these cavities exist by tens of thousands, and Sir David Brewster stated that in a specimen under his observation there were about 37,000 of these cavities. I am sure that in one of my large cut specimens there must be more than double that number. It is a very common thing to see hundreds of these cavities in the Ceylon specimens, partly filled with the fluids previously alluded to in these notes. But it is quite rare that they are found in the specimens from North Carolina. Still I have seen them in the transparent small fragments of deep blue crystals, and sometimes in the transparent light-colored ones. In one specimen of the latter, I discovered some most interesting cavities, which contained, beside the *fluid*, each a *single cubic crystal*, Figs. 1, 2, and 3, Pl. 2. I had never observed an included crystal in any cavity in the numerous Ceylon

specimens which I have examined. These cubic crystals have the exact form and appearance of those in the *Emerald* described herein.

In regard to the microscopic crystals in *Sapphire*, having described and figured them in the papers before alluded to, I have little to add now. Further observation has confirmed what I then stated regarding the radii of *Asteria*. Very recently I have received a number of these *Asteria* of various colors, blue, white, red, and dove-color; several three-quarters of an inch in diameter. The red and purple specimens are of peculiar beauty, and when examined in the sun, or any strong light, they both exhibit the microscopic acicular crystals with peculiar beauty, displayed as they are in hexagonal form, and reflecting the spectral colors. The *Ruby Asteria* is certainly among the most beautiful objects in nature, and the purple are very little less so.

In some crystals of *Corundum*, there is a strong bronze reflection, and this is the case with some of the large hexagonal crystals which were imported by Mr. S. S. White from India for commercial purposes, and which he distributed with so much liberality to our mineralogists. These bronze crystals have also been found at the Black Horse and Village Green localities in Delaware County, Pennsylvania. When examined with a good power, these bronze reflections are at once seen to be caused by minute acicular crystals, and these may sometimes be seen in bunches.

A pale *Ruby*, "Rubicelle," which I lately received from my friend Hugh Nevill, Esq., Ceylon, about three carats, is a most interesting and beautiful *gem*. It has the depth and brilliancy almost of the diamond. It is nearly of a rose-color, and is perfectly transparent. It is cut with a top table and not entirely symmetrical. Its refractive power is unusually great. Yet when this brilliant transparent *gem* is examined with a high power and strong light, the whole mass may

¹ Proc. Acad. Nat. Sci., 1869.

be seen to be filled with long acicular crystals in three directions, parallel to the prismatic planes, and interspersed are numbers of very minute and delicate cuneiform crystals.¹ It has also a small cloud of exceedingly small cavities.

Another remarkable specimen may be mentioned here, which has small cavities and minute microscopic crystals. It is of a pale yellow or straw-color, and of a depth and brilliancy scarcely exceeded by the diamond.

During the examination, about two years since, of some hundreds of small crystals of *Sapphire*, perfectly transparent to dark blue, I discovered one which had very singular plumose impressions on the planes of the prism. This induced me to examine carefully all those which I subsequently procured, and I have now over a dozen specimens which exhibit this very singular character.² I am entirely at a loss to discover the cause of this form of minute impressions on so hard a substance. It evidently has been formed by some collateral mineral substance, against which the molecules in crystallization have been arranged.

Diamond. — The hardest of all substances stands first among *gems*. It has not, however, much interest to the microscopist, as no cavities with fluid have been, so far as known, observed, nor has it included crystals of foreign substances. They are often very imperfect, containing rifts and discolorations. Some of my specimens have beautiful triangular impressions on the surface of the planes. My friend, Dr. Hamlin, of Bangor, Maine, is engaged on an extended work on the diamond. Such a work is much needed, and I know no one as capable as he to accomplish it. This gem sometimes occurs of various colors. In my cabinet I have six different colors.

REFERENCES TO PLATE 2

Fig. 1, 2, 3, Plate 2. Represents cavities and crystals in a specimen of transparent *Corundum* from Franklin, North Carolina. In no other specimen of the numerous ones

I have examined have I found cavities with a fluid and included crystals both, while it is very common in the Ceylon *Sapphires* to have cavities without an included crystal.

Fig. 4. A *Sapphire* from Ceylon, given to me by Dr. Ruschenberger, has cavities without fluid; the cavities being in the form of crystals in the larger ones, but in the numerous small ones subrotund. These cavities are interspersed throughout the mass with numerous acicular crystals running generally in two directions.

Fig. 5. A specimen of blue *Sapphire* (Ceylon), with four nearly perfect sub-hexagonal crystals, somewhat flattened. These are surrounded by an immense number of minute cavities, some of which anastomose. The crystals seem to be filled with a black fluid. There are also very minute acicular crystals.

Fig. 6. In the same specimen with the above, there is a group of very different crystals which are here represented. These can only be seen with a proper angle of light. Then they reflect all the colors of the spectrum. This group consists of very perfect cuneate and acicular crystals, and is somewhat like that figured in my pl. 9, fig. 2, Proc. Acad. Nat. Sci., May, 1869, but the crystals are much more defined and perfect than in that plate.

Fig. 7. Represents a small blue *Sapphire* one-fourth of an inch long. The very remarkable plumose impressions cover all the six prismatic planes.

Fig. 8. A blue *Sapphire* similar to Fig. 7, about three-sixteenths of an inch. The prismatic planes here are covered with impressions more in a dotted form. These two (Fig. 7 and 8) were examined with a power of one hundred diameters.

Fig. 9. A specimen of *Zircon* from Ceylon has very singular, dark brown, elongated fusiform maculations in one direction. These are surrounded with numerous dotted ones.

(Continued on page 254)

¹ Proc. Acad. Nat. Sci., May 11, 1869.

² Figs. 7 and 8, Pl. 2.

the customer and the jeweler. Neither have been educated to appreciate quality in colored stones. Granted, few Americans would pay \$350 for an aquamarine today, nor will they do it tomorrow or ten years from tomorrow unless the jeweler first educates himself and then his customers. As a first step the American jewelry industry should demand a better make in his colored stones.

The Brazilian lapidary is well aware of this situation and that is the reason we see so many "fisheye" aquamarines in American jewelry stores. He does his good work on his good stones for the Brazilian trade. As one remarked about the American trade. "They buy by the carat, don't they; why should I cut away weight when they will not pay for a properly proportioned stone?"

"Inclusions"

(Continued from page 236)

Fig. 10. Among all the numerous specimens of *Moonstone* which I have examined I have found two only with "inclusions." These have numerous parallelograms which look like cavities, but may be true crystals of some foreign substance. There is no appearance of fluid in them.

Fig. 11, *a, b, c, Emerald*. A very fine specimen in my collection is filled with exceedingly interesting cavities with included cubic crystals, enveloped by fluid. The forms of the cavities are exceedingly varied, and the cubic crystals — generally *two*, a small and larger one — are remarkably perfect. These characters make this specimen one of very great interest.

Fig. 12 and 12*a*, *Beryl* from Unionville, Pennsylvania. Fig. 12 represents a remarkable biangular cavity with a cuboid crystal at one of the interior angles — has no fluid. Fig. 12*a* represents in the same specimen two cavities with fluid and air bubbles. Both figures represent the numerous irregular cavities and imperfections which exist throughout the mass.

Note. — I have made these drawings with great regard to correctness, and the artist has well represented them.

Freaks & Rarities

(Continued from page 241)

disappeared from the market when news of this spread.

Ordinarily, ulexite has been used for making cat's-eyes but it is extremely soft and fragile. The cat's-eye effect is exceptionally strong, however, and it is worthwhile to take the considerable trouble involved in preparing the stone. The "television" effect referred to above can perhaps be found also in the finer qualities of satin-spar gypsum from England.

CORRECTION

An error occurred in the placement of one of the photomicrographs in the article entitled "Electron-Microscopic Observation of Aragonite Crystals on Cultured Pearls," in the Fall, 1955, issue of *GEMS & GEMOLOGY*.

A duplicate of Figure 5 was inadvertently used for Figure 2. The photomicrograph for Figure 2 is shown herewith.

