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IN MEMORIAM ROBERT M. SHIPLEY

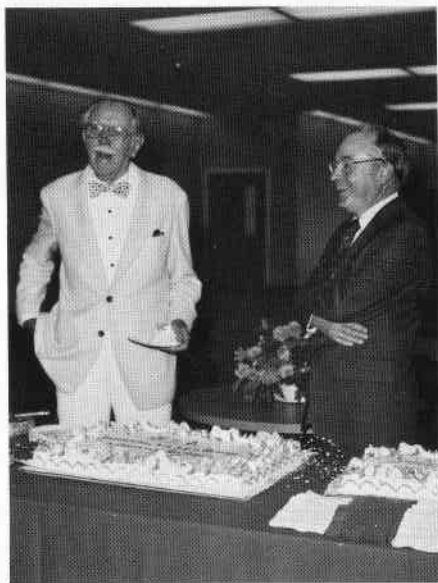


When Robert M. Shipley passed away in his sleep on April 18, a giant was lost to the jewelry industry. The father of gemology in America, Shipley was the 129th diplomate of the Gemmological Association of Great Britain. When that award was granted, apparently, there was only one jeweler's refractometer in America, and the state of knowledge of gemology in this country was primitive.

Robert M. Shipley was born in southwest Missouri on February 21, 1887. A short time later, the family moved to Monett, Missouri. After being tutored by a maid in the family, young Robert was sent to a military academy in Wisconsin and later attended the University of Wisconsin, dropping out in his junior year when his father died. He returned to the then family home in Wichita, Kansas. He held a variety of positions in

Wichita, including working for the Kansas Gas and Electric Company. While working for the utility, he married the daughter of a local jeweler. When he was asked later to take over the business, he did so. Shipley never really liked the jewelry business at that stage, but he did add other elements to the store, such as china, giftwares, leather goods, and an interior decorating facility. Several years later the business ran into difficult times, as did his marriage. He was divorced, left Wichita, and ultimately traveled to Paris, France, to study at the Louvre where he met Beatrice Bell, whom he later married. During the latter part of his European sojourn, Shipley took the correspondence courses of the Gemmological Association of Great Britain. In 1929, he went to London to prepare for and take the examination that would earn his diploma.

It was to see Beatrice Bell that he



went to California in 1930. There, he opened a small art gallery that was not too successful in the depression year of 1930.

Before Shipley had left the jewelry business, his early success had led to his election as president of the Kansas Retail Jeweler's Association, and later he was a regional vice-president for the then American National Retail Jeweler's Association. On the street one day in California, he encountered Armand Jessop, who was at that time regional vice-president for the far west for ANRJA. Upon learning what Shipley had been doing in Europe, Jessop asked him if he would give some lectures on the subject of gemology to local jewelers. This was set up in the extension division of the University of Southern California, and the first classes were given in 1930. These were, as extension division classes, offered on a one or two night per week basis. When Shipley went to his first class, he thought no one had responded because there was no one in the room which had been assigned to the class. It was not until a few minutes later that he found a notice indicating that the class had been moved to another larger room where he found 80 people waiting. Many of the jewelers attending the classes had to travel great distances, and one in particular, J. E. Peck of Campo, California, near the Mexican border, persuaded Shipley to produce the course in a written form that could be studied at home. At about the time he concluded that this might have a chance for success, he raised enough

money to pay less than \$100 for an old model A Ford and a typewriter. He started to write a four-course program in gemology consisting of a Fundamental Course, a Colored Stone Course, a Diamond Course, and an Advanced Gemology Course. The latter essentially was the use of gem-testing equipment and identification.

Shipley had so little money it was almost essential that he sell a course in each city so he could start getting the \$8.00 per month per student coming in to sustain him as he wrote the course. His wife, Beatrice Bell Shipley, was enormously helpful, both in encouraging him to continue a very difficult task of selling an idea, and in assisting him financially. About the time the initial course was completed, Robert Shipley, Jr. joined his father.

Robert Jr., a brilliant young scientist, developed most of the gem-testing instruments that differed from the mineralogist's array of equipment. He was responsible, for example, for the dark-field illuminator binocular microscope, for the polariscope employing the then new Polaroid plates and for many other innovative ideas. The father was the magnificent salesman of an abstract idea, and the son gave it a solid scientific backing. There is no question but that Mrs. Shipley and Robert Shipley, Jr. were important in the early stages of the Gemological Institute of America.

In those early days, there were a number of students who were right up to date on Shipley's writings at all times and waiting for the next lesson to be completed so they could com-

plete their courses. GIA's first graduate was Frederick B. Thurber, of the firm Tilden-Thurber, which still is going strong in Providence, Rhode Island and vicinity. Robert Jr. assisted his father in writing the advanced courses on Colored Stones and Advanced Gemology, which in a later revision was retitled Gem Identification.

One of Shipley's early selling points on studying gemology was the intent, when numbers justified it, to form an organization he described as being similar to "the guilds of old." This would be a membership organization for which there were two prerequisites; one, knowledge and two, ethics. The idea was that the firms solicited for enrollment in the gemological courses were those which did the kind of business that their peers could be proud to join in a guild type of organization. The founding date given for the American Gem Society is 1934, but Shipley had been using that theme several years before. It was not until a number of years later that the American Gem Society became entirely separate from the Gemological Institute of America. In those early days, Mrs. Shipley was the Chief Administrator of the organization while Robert M. Shipley did the selling, mostly on the road, and the writing, both on the road and at home. Mrs. Shipley was assisted by Dorothy Jasper Smith, who joined the staff in 1932 and, with the exception of leaves to have her two children, served GIA for 31 years. In those early days, Shipley was President of GIA. After the late Edward Wigglesworth, Ph.D.,

Curator of Gems & Minerals at the Boston Museum of Natural History, became interested in and studied gemology, Shipley asked the Board to make Wigglesworth President and Shipley became Executive Director.

There were many jewelers who were of enormous help to Shipley in those early days. He used to point with real appreciation to such men as Godfrey Eacret of Shreve, Treat and Eacret of San Francisco, George Brock of George Brock and Company, Los Angeles, Edward F. Herschede of Cincinnati, Leo Vogt of St. Louis, Percy Loud of Detroit, Paul Juergens of Chicago, John Vondey of San Bernardino and many more. Later James Donovan and Fred Cannon, both of Los Angeles, were of great help to Shipley.

After the courses were completed, about 1935, their structure and numbering was changed to conform to the four-course arrangement mentioned earlier. The Fundamental Course was called Course #012, the Colored Stone Course was #1, the Diamond Course was #2, and the Advanced Gemology #3. This course arrangement lasted until after Robert M. Shipley's retirement. In 1938, the Institute was moved from the old small studio apartment on the corner of 6th and Alexandria in Los Angeles, into an apartment building that had been built with the idea of housing the Institute by the Shipleys. The idea was that the Institute could occupy two apartments initially, and then, as it grew, additional apartments could be occupied. The plans were interrupted by World War II. Robert Shipley, Jr.

was an officer in the Air Force Reserve and anticipating his call-up, which did occur in Spring of 1941, Mr. Shipley approached Dean Edward H. Kraus and Professor Chester B. Slauson of the University of Michigan, for a Director of Education. In June of 1940, Richard T. Liddicoat, Jr. was hired. One year later in the spring of 1941 Alfred L. Woodill, Robert Shipley's nephew, who would later become Executive Director of the American Gem Society, also joined the organization. Shipley was very concerned by what might happen to GIA during a war, and he turned the Institute over to the Board of Governors acting for the industry so that an endowment fund could be raised to insure the existence of the Institute through a war-time period. The expected decimation of enrollments did not occur, and ably assisted by Virginia Hinton and Elizabeth Brown on the educational side, Shipley weathered the war years and the Institute emerged in excellent condition.

With the help of the G.I. Bill, which went into effect, as far as GIA was concerned, in late 1946, the Institute prospered and the student body was enlarged enormously during this period. Many people who were to become key factors in the growth of the Institute joined the staff. Liddicoat who had returned from the service in February of 1946, was working with George Switzer, Ph.D., who later became Curator of Gems & Minerals at the Smithsonian Institution, and during this period Lester

Benson, Kenneth Moore and Robert Crowningshield were all added to the staff, as well as Lawrence Copeland and others. Mark C. Bandy, Ph.D., was on the staff for a fairly short period of time and opened GIA's Laboratory in New York City in the Fall of 1948. GIA's first Eastern Laboratory had been opened in Boston by Edward Wigglesworth who was serving GIA without compensation. Upon his death in 1945, the laboratory was closed and did not reopen until Bandy and Crowningshield went to New York in 1948.

It was in 1948 that Shipley announced his intention of retiring in 3½ years, planning to step down at the end of 1951. Circumstances led to a 3-month postponement of that retirement date, which was then made March 31, 1952. Thus, after 21 years at the helm of GIA, Robert M. Shipley retired.

The years following his retirement were spent largely in South Laguna Beach in an area of the California coast the Shipleys loved. His beloved wife, Bea, passed away in July of 1973.

On February 18, 1977, three days before his 90th birthday, a vital Robert M. Shipley visited GIA's new headquarters in Santa Monica. A reception was held in his honor by GIA's Board of Governors and the staff. He charmed the student body with a fascinating recounting of salient events from the early days of GIA.

Robert M. Shipley lived a long and productive life. He will be missed by many, but he left his mark.

Differentiation of Black Pearls

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Introduction

The term black pearl has been generally used without clear-cut definition. In addition to naturally colored pearls, various kinds of artificially colored pearls are also called "black pearls." The naturally colored black pearls (hereinafter to be referred to as cultured black pearls), which are barely known to the world, are obtained from black-lipped pearl oysters.

Our main purpose is to describe the history and nature of the cultured black pearls. Methods are presented for distinguishing them from other artificially stained black pearls, especially from pearls blacked by the so-called "silver salt treatment."

Cultured Black Pearls

History and Present Situation

Reportedly, the first trial of black pearl cultivation in Japan, mainly blister pearl, using black-lipped pearl oysters (*Pinctada margaritifera*) was carried out in 1912 in the Miyakojima

Islands in Okinawa Prefecture (the Ryukyu Islands at that time). For several decades since then, a great deal of effort has been made by many pearl culturers to cultivate black pearls. However, all their attempts failed because of the great difficulty involved in the cultivation technique. In the early 1970's, the present Ryukyu Pearl Co., Ltd., succeeded in producing black pearls on a profitable basis. This was nearly 20 years after the initiation of the project in 1951 on Ishigakijima Island, Okinawa.

At present, three main regions produce cultured black pearls: Yaeyama Islands (Ishigakijima, Iriomotejima and other), Tahiti and the Fiji Islands.

Although their existence has been known by some professionals for about 60 years, black pearls of gem quality, namely, perfectly round, real black and flawless, have rarely been seen in the market. The reason for the scarcity is the inability of most



Figure 1. Left: black-lipped pearl oyster. Right: Akoya pearl oyster.



Figure 2. Pearls from black-lipped pearl oysters. From left to right: silver, gold, brown-black, black and green-black.



Figure 3. Microscopic observation of stripe patterns of Akoya pearl (left) and cultured black pearl (right) (60x).



Figure 4. Scanning-electron microscope observation (x15,000) of the cut surface of a black pearl (above) and its schematic diagram (below).



Figure 5. Artificially blackened pearls.



Figure 6. Blue pearl (left) and black pearl (right). Outer appearance (above) and sections (below).



Figure 7. Cultured black pearls. Image of conventional color film (above) and infrared color film (below).

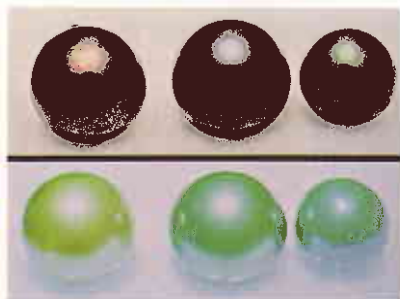


Figure 8. Silver treated black pearls. Conventional color film (above) and infrared color film (below). Compare the infrared image with that of Figure 7. The color tone is quite different.

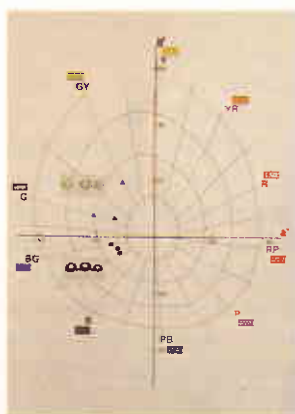


Figure 9. Chromaticity coordinates.

growers to cultivate them.

Presently, the quantity of gem quality black pearls is so limited that the annual production is estimated to be about 2,000.

Culturing Method

Black-lipped pearl oysters are large bivalves which live in tropical or subtropical seas. The inner surface of the shell is an intensively iridescent white silver. The edge of the shell is lined with a characteristic brown-black belt (*Figure 1.*)

The process of cultivation is very similar to that of ordinary pearls: A tiny bead which is made of mussel shell (called the "nucleus") is inserted into a black-lipped pearl oyster together with a piece of the mantle from another living oyster. The oyster is then placed in its seawater habitat and cultured so that the nacre layer can be formed around the nucleus. As the black-lipped pearl oysters are very sensitive, many of them, after having the nucleus inserted in their bodies, reject the nucleus or die. Only 20 or 30 per cent of them eventually serve as pearl-producing oysters during the two-year cultivation period. Of the pearls harvested from these surviving oysters, only 5 to 10 per cent are of gem quality.

Color Tone

Cultured black pearls may be classified into five groups depending on their color. For convenience the following designations are given: silver, gold, brown-black, green-black and black. Among them, the brown-black, green-black and black are tentatively called "black pearls." Silver and gold

pearls can also be obtained from the Akoya and silver-lipped pearl oysters as well as black-lipped pearl oysters. Therefore, because they are more plentiful, they are of less value than the brown-black, green-black and black pearls and, of course, cannot be called black pearls (*Figure 2*).

Structure and Composition

As is well known, the characteristic iridescence and color tone of pearls are derived from the pearl layer which is formed over the nucleus. Microscopic observation of the pearl layer discloses a regularly layered structure of aragonite, a polymorph of calcium carbonate similar to calcite. The characteristic striped pattern of the layers as observed over the surface through the microscope is shown in *Figure 3*. The layered crystal plates are recognized on the cut surface (*Figure 4*) through the use of the electron microscope.

Lying between the crystal layers are organic sheets, specific to pearls, which play a role of sticking the crystals together. The major component of the organic sheets is a hard protein called "conchiolin." Other substances such as glycoproteins and pigments also have been identified.

The only reason black pearls are black is that the brown-black pigment, characteristic of black-lipped pearl oysters, is part of their organic sheets. As far as this pigment is concerned, it has not been chemically studied yet. Only one report on the composition of their shells, not of pearls, makes it possible to guess the composition of the black pigment.*

*Yoshishige Horiguchi Bull. Japan. Soc. Sci. Fish. 25, 391-401, 675-679 (1959).

Analogous (Imitation) Black Pearls

Pearls Blackened by

Silver Salt Treatment

These are blackened pearls very similar to the cultured black pearls previously mentioned. They have been on the market since the 1930's and are more popular than the cultured ones. Several methods are being used to make pearls black, among the most popular is the "silver salt treatment." The coloration is based on the chemical reaction using various kinds of silver salts to make silver precipitate in

the nacre so that the color of the nacre turns black. Thus blackened pearls are very similar in color to the cultured ones. They also have the same color of brown-black, green-black and black, which makes it difficult even for the experts to distinguish them from cultured black pearls by observation alone. Examples of this treatment can be seen in *Figure 5*.

Blue Pearls

It is the blue pearl which is often considered a black one by mistake, although it is not an imitation of the

TABLE 1.

**Comparison of the Mechanisms of Color Formation
Between Conventional Color Films and Infrared Color Films**

Conventional Color Films

spectrum zone	blue	green	red	infrared
film layer sensitivity	blue	green	red	
dyes formed in film layers	yellow	magenta	cyan	
resulting colors in transparency	blue	green	red	

Infrared Color Films

spectrum zone	blue	green	red	infrared
film layer sensitivity	blue	green	red	infrared
film layer sensitivity after yellow filter		green	red	infrared
dyes formed in film layer		yellow	magenta	infrared
resulting color in transparency		blue	green	red



Figure 10. Brown-black pearls. At left is the cultured black pearl; at right the silver treated. Conventional color image (above) and infrared image (below).



Figure 11. Green-black pearls. Left: cultured black pearl. Right: silver treated. Conventional color image (above) and infrared image (below).



Figure 12. On the right is the imitation. In the center and on the left are cultured black pearls.



Figure 13. The cultured black pearl (center) is surrounded by silver treated black pearls.



Figure 14. At the extreme right is the treated pearl. The others are genuine.



Figure 15. Images of infrared color film with varying exposures. Above left: optimum exposure. Above right: one scale in excess of the optimum exposure. Below left: three scales in excess. Below right: five scales in excess. The cultured black pearl (to the left of all four pictures) is clearly distinguished from the silver salt treated pearl (to the right of all four pictures).

black pearl. Most of the blue pearls are obtained from Akoya pearl oysters and not from the black-lipped oyster. They have bluish colors of transparent pale blue, pale green or deep blue, from which they derive their name.

Further explanation is needed in regard to the cause of blue tones. The tones chiefly come from colored contaminants in the nacre or between the nacre and nucleus. During the period of pearl cultivation, some organic matter becomes incorporated in the shell due to the physiological changes of the pearl oyster. The organic matter causes a brown blemish which gives the pearl a blue appearance when seen through the translucent nacre.

Although the name "blue pearl" often makes one think the blue pearl is a black one, the structure and composition of a blue pearl differ from that of a black pearl, as shown in Figure 6.

Differentiation Methods

It should be remembered that in this present article, the genuine black pearl means cultured black pearls hav-

ing color tones of brown-black, green-black or black which are obtained from black-lipped pearl oysters. These are of gem quality. On the contrary, the blackened pearl means pearls colored by the silver salt treatment as previously described.

There has been an increasing demand by jewelers to differentiate these two types of pearls since appraisers often have been faced with the difficulty of doing it. We tried some methods, among which the following differentiations were found to be useful. Infrared color film yielded especially good results.

Differentiation by Color Image On Infrared Film

When the cultured black and blackened pearls are photographed with color infrared film (Kodak, Ektachrome Infrared Film, IE 135-20), a clear difference between the two can be observed in the color tone of the images. (See Figures 7 and 8.)

For a better understanding of the technique, first let us discuss infrared film. Conventional color film consists

TABLE 2.

Analysis of the chromaticity on the infrared images

		Y	x	y	L*	a*	b*
Figure 8 (Ag treated Akoya pearl)	1	49.93	0.3322	0.3702	76.03	-11.48	19.06
	2	49.26	0.3014	0.3423	75.61	-13.82	6.50
	3	33.63	0.2878	0.3547	64.69	-21.20	7.14
Figure 7 (Cultured black pearl)	1	34.21	0.2758	0.3152	65.12	-12.92	-4.50
	2	34.57	0.2734	0.3107	65.40	-12.33	-6.01
	3	16.29	0.2642	0.3225	47.34	-15.81	-3.05

*measured by spectrophotometer (Hitachi M 307).
calculated according to 0-0 SI 10 W 10 (JIS Z 8722)

of three image layers sensitive to blue, green, and red, whereas the image layers of infrared color film are sensitized to green, red and infrared. Accordingly, the differences in intensity of infrared ray reflections on materials results in differences of color tones from the images (see *Table 1*).

As shown in *Figures 7 and 8*, cultured black pearls give blue images while, in contrast, images of blackened pearls are greenish blue to yellow-green. Whatever different colors — brown-black, green-black or black — cultured black pearls may have, they give the same blue images which are quite different from those of blackened pearls. Other examples as seen in *Figures 10, 11, 12, 13 and 14* show this fact. These color characteristics can be used as one of the effective methods of differentiation.

Next, the analysis of the chromaticity was carried out on the images of *Figures 7 and 8*. (See *Table 2 and Figure 9*.)

As indicated in *Table 2 and Figure 9*, the chromaticity of the cultured

black pearls belongs to the blue region, while blackened pearls have their chromaticity in the region from green to yellow with probable contamination of red. Although the mechanism has not been proven yet, the color difference between the two kinds of black pearls seems to result from the infrared reflection rates being different between genuine and imitation black pearls. This difference is due to the infrared color film which gives a red image when it is exposed to infrared rays.

There are two requirements necessary in order to obtain a clear differential image. First, the light source should be a Xenon lamp. The intensive emission spectrum of this lamp in the infrared region ($0.82\text{--}0.99\ \mu$) may contribute to the successful differentiation of the two pearls. Secondly, a series of images photographed with varying exposure is advisable, from optimum to excessive, since it is rather difficult to differentiate between them with only a single photo. By photographing in a series as recommended, clear differen-

TABLE 3
Element Composition of the Surface Layer of Pearls
by X-ray Fluorescence Analysis.

Samples	Elements														
	Ag	Sr	Zn	Cu	Ni	Fe	Co	Mn	Cr	Ca	K	S	P	Si	Al
Akoya pearl	—	++	—	—	—	—	—	—	—	+++	+	—	—	—	—
Black-lipped pearl	—	+++	—	—	—	—	—	—	—	+++	++	—	—	—	—
“Ag treated” Akoya pearl	++	++	—	—	—	—	—	—	—	+++	±	—	—	—	—

+++ : most clearly detected

++ : clearly detected

+ : detected

± : not clearly detected

— : not detected

tiation will be obtained. *Figure 15* shows the difference in color tone of images taken at various exposures. Notice that the difference between the two becomes clearer with excessive exposure.

Differentiation by X-Ray Fluorescence Analysis

If pearls are treated with silver salt, silver will be detected by X-ray fluorescence analysis*. Since cultured pearls do not contain silver, the extraordinary content of it suggests that it has been treated with silver salt. The most favorable reason for using this analysis is that it can analyze the elemental composition without destruction of the samples. Elemental composition of the surface layer of pearls (pink pearls from Akoya pearl oyster), cultured black pearls and blackened pearls are shown in *Table 3*.

As expected, silver was detected only in the blackened pearls. The X-ray fluorescence analysis may be used as one of the methods for distinguishing cultured black pearls from the blackened ones. The only *unfavorable drawback* to this analysis is that the *sample pearls turn to brown-black from X-ray irradiation*.

Table 3 shows that presence of potassium and strontium in the cultured black pearl. Further studies are required in order to confirm which

conditions, physiological ones of the oyster or environmental ones such as seawater, nutrition, and so forth, cause the presence of these elements.

Differentiation by Hardness Measurement

The nacre of the blackened pearl is more fragile due to the alteration of its surface by various chemicals during the coloring process, especially silver salt treatment. By measuring the tendency of the decrease in its hardness with a micro hardness testing machine, we can judge whether sample pearls are chemically treated or not. A decrease of about 40 per cent in the hardness caused by the coloring process was demonstrated by a Vickers hardness testing machine. In addition, an indication of surface deterioration, such as exfoliation and cracks are occasionally found on blackened pearls by careful observation with a microscope.

Other Methods of Differentiation

None of the blackened pearls fluoresce under ultraviolet irradiation. The cultured black pearls, on the other hand, especially those of middle grade, emit yellow-red fluorescence from the hollow and the micro niches on the surface. The emission is limited to the spot of such an irregularity on the surface (the cultured black pearls of high quality as previously defined emit no fluorescence because of the complete smoothness of the surface). However, there are so many exceptional cases in these properties that careful testing is required to adequately identify the cultured black pearl.

*Being irradiated with a powerful X-ray, each element contained in the sample is excited to emit characteristic X-rays, the wave lengths of which are measured spectroscopically to confirm the presence of a corresponding element in the irradiated area.

Inclusions in Agate and Their Origins and Significance

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INTRODUCTION

As the prices of diamonds and many colored stones steadily increase, the consumer who desires natural stones will exert heavier pressure on the less expensive and more abundant colored stones such as the chalcedony gems. In spite of its abundance, little is known about the geological origins of this gem because it has generally been treated as a laboratory curiosity and the field relationships and genesis of this gem have not been widely studied (Jones, 1951; Sinkankas, 1961). Lane (1911) did some field related studies on the occurrences of agate in the Keweenaw Peninsula of Michigan, and Zarins (1977) demonstrated that the occurrence of agate in the Cathedral Mountain area of west Texas is related to an important geological time line, that agates could be used to correlate volcanic rock units, and that agates were largely a product of weathering.

As a gem material, agate offers the jeweler a number of advantages over many other colored stones. It is currently inexpensive and attractive to young, less affluent buyers whose trust can be built early. A large inventory can be handled and it is easy to identify so there is no incentive for imitations to be produced. Many of the inclusions in agate are of such a nature that they may serve as the subject of a stone. Many jewelers, however, lack an in-depth knowledge of agate sufficient to enable them to take full advantage of its sales potential. The following study is devoted to identifying and interpreting the nature of inclusions in agates. The study is based on comparing the similarities and differences of 3,901 agates, 794 from the Lake Superior region of Minnesota and Michigan; 734 from the Coya Mito region, Chihuahua, Mexico; 609 from the Ojo de Laguna Region, Chihuahua, Mexico; 929 from the

Moctezuma region, Chihuahua, Mexico; 66 from the Cerro de Mercado region, Durango, Mexico; 127 from various regions of Brazil; 62 from Botswana, Africa; 238 from the Madras, Oregon region; 30 from the Crawford, Nebraska region; 104 from the Glendive, Montana region; and 208 from the Cathedral Mountain area, west Texas.

Contrary to the popular notion that no two agates are alike, the results of this study show a great deal of similarity between all agates, regardless of geological age or geographic source.

Pre-genetic inclusions (inclusions formed before the agate nodules crystallized) in agate nodules are very common in geologically young agates but usually rarer in old agates and include such things as aragonite crystals and gypsum crystals. These inclusions may be completely replaced by chalcedony through time, and in geologically old agates they may be absent. For example, sulfide inclusions in geologically young agates such as those from the Tertiary of Texas may be replaced by oxides in old agates such as those from the Late Precambrian (over 300 million years ago) of the Lake Superior region. Many inclusions, such as decomposition products of the host rock and low temperature polymorphs of aragonite and gypsum indicate that agates formed under conditions of low temperature (25-30°C) and pressure. Syngenetic features are those features the agate acquired during its crystallization. These include bands, escape tubes, plastic deformation structures, and bubbles.

Structure of the Agate Nodule

Generally, a fresh agate nodule consists of a zone of banded spherulitic chalcedony that frequently encloses a pocket of euhedral quartz crystals (*Figure 1, Table 1*). This model may be repeated one or more times within the same nodule. Crystals of other minerals such as aragonite and calcite, decomposition products of the host rock, or membranous cristobalite (Lebedev, 1967), enclosed in chalcedony, may occur on the outside of the nodule but separate from the banded chalcedony portion (*Figure 1*). Decomposition products of the host rock may include epidote, chlorite, limonite, zeolites, calcite, aragonite, and other secondary minerals.

Concentric bands are the most prominent structural feature of the agate nodule and make up the area most likely to be used for gem purposes. Keith and Padden (1963, 1964a, b) developed a general theory of spherulitic crystallization, and they noted that chalcedony and agate are composed of spherulite-like crystal aggregates. Primary nuclei of SiO_2 grow and eventually give rise to radially fibrous, polycrystalline aggregates (*Figure 2*) in which crystal growth is at small angles to the fibre axis, rather than along preferred crystallographic orientations as in euhedral quartz crystals. Oehler (1976, p. 1146) demonstrated that spherulitic growth occurs in "... multicomponent systems in which component segregation occurs during crystallization and in which coefficients of diffusion in the liquid phase are small

TABLE 1. Types of Inclusions found in various agates. Note the

Source of Agate and Geological Age	Lake Superior Region Minnesota, Michigan, Late Precambrian	Ojo de Laguna, Chihuahua, Mexico Eocene- Miocene	Coya Mito, Chihuahua, Mexico Eocene- Miocene	Moctezuma, Chihuahua, Mexico Eocene- Miocene	Alpine, Texas Area (Cathedral Mountain) Eocene- Miocene
Type of Inclusions					
Bands of Spherulitic Chalcedony	x	x	x	x	x
Euhedral Quartz	x	x	x	x	x
Membranous Cristobalite	Rare	x	x	x	x
Weathering Products of host rock	Rare	Abundant	Abundant	Abundant	Abundant
Escape Tubes	x	x	x	x	x
Flow or plastic Deformation structures	x	x	x	x	x
Bubbles	x	Rare	x		
Sagenite (See Crystals, Crystal Pseudomorphs, Crystal molds, Plumes)					
Crystals	Rare	x	x	x	x
Aragonite		x	x	x	x
Rutile	x	x	x		
Goethite	x	x	x		
Calcite	Rare	x	x	x	x
Gypsum		x			
Barite		x	x	x	
Siderite		x	x	x	
Crystal Pseudomorphs	x	x	x	x	x
Aragonite	x	x	x	x	x
Calcite				x	x
Gypsum	Abundant			x	
Barite		x	x	x	
Crystal Molds					
Barite	Common	Rare	Rare	Rare	Common
Calcite	Common	Rare	Rare	Rare	
Aragonite		Rare	Rare	Rare	Common
Plumes					
Marcasite	Rare				Abundant
Limonite	Rare				Abundant
Pisolites	Rare			Common	Abundant
Stalk Forms	x	x		x	x
Chromatographs				x	
Globular-collimorphic Textures	x	x	x	x	x

similarities of all agates regardless of geographic source or geologic age.

Botswana/land, South Africa probably Late Precambrian	Brazil, All Areas Age not Determined	Corro de Mercado, Durango, Mexico Eocene-Miocene	Crawford, Nebraska Area Oligocene	Glendive, Montana Area Devonian- Cretaceous	Madras, Oregon Area
x	x	x	x	x	x
x	x	x	x	x	x
Rare	Rare			x	x
x	Rare	x	x	Rare	x
x	x	x	x	x	x
x	x	x	x	x	x
x		Common			
Rare	Rare x	Common x	x	x	
	x	x	x	x	x
	x		x		
		x	x	x	
			x	x	
				Common	
x	x			x	
				x	
					Common
x			x	x	x

compared with crystal growth rates." The only way this condition can occur in a colloid is in a solution in which the concentration is well above the saturation value. A viscosity threshold must be reached for spherulitic crystal growth, or non-spherulitic crystal growth will occur (Oehler, 1976). As the (silica) concentration of a solution increases, the viscosity threshold will be attained and spherulitic crystal growth will occur producing banded chalcedony, until the colloid is consumed or diluted (Oehler, 1976, p. 1148). In low viscosity or highly diluted (silica) systems, euhedral quartz crystals or quartz overgrowths will occur. Mackenzie and Gees, 1971, precipitated quartz crystals from undersaturated siliceous solutions under surface conditions. Thus, the banded portion of the agate nodule is indicative of the stage of growth in which the viscosity of the silica solution was high and the euhedral quartz crystals represent the time line in the agate nodule in which the viscosity of the siliceous solution became diluted or low.

Zarins (1977, p. 34) indicated that a natural, siliceous colloid commonly contains impurities which may be rejected from the chalcedony as spherulitic growth continues. The impurities become concentrated in the troughs between spherulites, which inhibits further crystal growth in these areas. This process favors continued spherulite growth at their tips while the troughs between crystal clusters fill with impurities and form bands.

Many theories have been advanced to explain the banding of agate.

Liesegang (1915) synthesized bands of silver chromate in a gelatin medium from silver nitrate and potassium dichromate. The silver chromate precipitated only when the solution was saturated with silver nitrate. The silver seeks a layer beyond the precipitate layer and when saturation occurs, another precipitate layer forms and the process repeats itself as long as the reactants are present in a supersaturated concentration. This idea was accepted by most workers and was well entrenched in Farrington's (1927) classic work on agates.

Many agate nodules contain banded zones with the inner bands extending in a long, tube like structure, all the way to the outer surface of the nodule (*Figure 3*). Many workers (Blair, 1936; Dake, 1950; Vanasse, 1958) have interpreted this as an entrance duct ("Einflusskanale," of Noegerrath in Liesegang, 1915) in which a saturated silica solution periodically filled the vesicle in which the agate nodule formed. As the water evaporated, a new layer of silica was deposited inside the nodule. Shaub (1955, p. 117-120) demonstrated this structure to be an escape tube by showing that more than one could be found in an agate nodule and that they had no preferred orientation. Many of the agates observed in this study exhibited this feature but it did not always extend to the outer surface. Furthermore, the inner bands displayed diapiric (piercing) deformation of the outer bands indicating that the agate was in a gelatinous state when the silica solution escaped from the nodule (*Figure 3*). As crystallization proceeds from a



Figure 1. Unweathered agate nodule from Coya Mito, Chihuahua, Mexico. The nodule shows banded, spherulitic chalcidony enclosing a pocket of Euhedral Quartz Crystals. The chalcidony engulfs membranous cristobalite and decomposition products of the host rock. Note siderite crystals below banded chalcidony in lower right. X0.5



Figure 3. Escape tube in agate. Specimen from Late Precambrian, Lake Superior Region, Minnesota. Note diapir deformation of dense, white bands. X2.



Figure 5. Bubbles in agate nodule from Cerro de Mercado Region, Durango, Mexico. X1.



Figure 2. Spherulitic chalcidony in polycrystalline aggregates. Specimen from Cottonwood Springs Basalt, Cathedral Mountain Quadrangle, west Texas. X360.



Figure 4. Flow structure causing plastic deformation in agate nodule from late Precambrian, Lake Superior Region, Minnesota. X2.



Figure 6. Bubbles concentrated in escape tube in agate nodule from Cerro de Mercado Region, Durango, Mexico. X2.

silica solution, the volume occupied by siliceous gel is squeezed within the nodule to the outside resulting in plastic deformation or flow structures (*Figure 4*). Flow structures are common to agates from all locations (*Table 1*).

Geologically older agates that have been weathered and/or transported often lack the zone of membranous cristobalite or decomposition products of the host rock. This is probably because this area is porous and absorbs water more readily. In some climates, such as in the Lake Superior Region, the wet porous area would be an area subjected to freeze-thaw destruction. Those agates that have been glacially transported very rarely have the cristobalite — host rock zone.

Bubbles

Some agate nodules may contain bubbles (*Figure 5*), the origin of which was initially difficult to understand. Winfree (1973, p. 82-95) demonstrated that chemical reactions take place in a rotating, spiral pattern; as the reaction goes to completion, heat may be generated causing the solution to boil. The spiral reactions also produced banded structures in the "Z reagent" media used by Winfree. It appears that the bubbles were trapped in the silica gel when it hardened. In some agate nodules from the Cerro de Mercado region, Durango, Mexico, the bubbles are concentrated in the "escape tube," (*Figure 6*) lending further evidence to Shaub's idea that material actually was forced out of the agate nodule.

Plumes and Dendrites

Plumes of metallic oxides and sulfides are abundant in the agates from the Tertiary volcanic rocks in the Alpine, Texas area (*Figure 7*). Such inclusions are also known from the agates of the Priday Ranch and the Eagle Rock area in Oregon. Plumes are also rarely encountered in the agates from the late Precambrian rocks of the Lake Superior region of Minnesota and Michigan (*Table 1*). In the geologically old agates, these structures probably have been destroyed by weathering as the plumed area is quite porous. The sulfide plumes are probably a late-stage crystallization product from a magma; they may occur in basaltic or rhyolitic rocks. Plumes show no evidence of having distorted the host agate — in fact, they appear totally engulfed by chalcedony. Dake (1950, p. 44) illustrated plumes free of chalcedony matrix. Upon oxidation, the sulfides yield oxides, and in geologically old agates, the plumes usually occur as the latter.

Zarins (1977) demonstrated that different types of plumes occur in different volcanic rock units in the Cathedral Mountain area of west Texas. The plumes in agates of the Cottonwood Springs Basalt are horizontal with respect to the land surface and, in the underlying Sheep Canyon Basalt, vertical with respect to the present land surface. Further, Zarins demonstrated that no agates occur in the younger Duff Tuff that overlies the Cottonwood Springs and Sheep Canyon Basalts or in conglomerates derived from weathering and erosion

of the Duff Tuff. Zarins postulated that weathering of the Duff Tuff and the consequent release of silica provided the material from which the agates were formed. He found no nearby igneous intrusions that could provide hydrothermal sources of silica and concluded that they originated under conditions of low temperature and pressure and not hydrothermally. The agates in the Cathedral Mountain Quadrangle, Texas, are an important index for correlation of rock units; their occurrences can be used as a geological time line.

Dendrites look much like plumes; however, there is a significant genetic difference in that dendrites are deposited as initial oxides, like pyrolusite, and not as an oxidized sulfide. Microscopic examination shows the dendrites are normally confined to the area between bands of chalcedony or in healed fractures in chalcedony and are essentially "two-dimensional" whereas plumes are "three-dimensional" and occur within the chalcedony crystal aggregates.

Sagenite, Crystals and Crystal Pseudomorphs

Sagenite is a "catch-all" term that applies to slender, needle-like inclusions of various minerals. Mayer *et al.* (in Myatt, 1972, p. 152-153) included zeolite, rutile, tourmaline, hornblende, actinolite, and cinnabar among the sagenite-forming minerals. This type of inclusion (*Figure 8*) occurred in practically all types of agate studied. Sagenite (see crystals, *Table 1*) included in the agates seen in this study consisted mainly of hollow aragonite needles

and secondarily of siderite, rutile, goethite, gypsum and barite. In many of the agates studied, chalcedony pseudomorphs after "sagenite" minerals were present, especially in the Late Precambrian agates (*Figure 9*). Most of the sagenite forming minerals are low-temperature such as aragonite, and are associated with low temperatures that would occur along with weathering and/or soil development.

Crystals are common inclusions within many agates. The geologically younger agates commonly contain unaltered aragonite, calcite, barite, gypsum, goethite, or rutile crystals. In the geologically old agates most of these inclusions are represented by chalcedony pseudomorphs. Goethite and rutile may form the nuclei about which tubes or eye-like structures grow (*Figure 10*). Goethite and rutile are usually unaltered in even the geologically old agates, and they are common crystal inclusions. Chalcedony from the Oligocene, Chadron Formation of Nebraska frequently occurs as complete or partial pseudomorphs after gypsum (Vondra, 1961). In numerous instances, the agate inherits the cleavage of gypsum (*Figure 11*); thus, much of the parallel banded varieties of chalcedony referred to as onyx or sardonyx (*Figure 12*) are probably chalcedony pseudomorphs after gypsum.

In geologically older agates, many of the crystals are represented only by chalcedony pseudomorphs. The Late Precambrian agates from the Lake Superior region commonly contain pseudomorphs of chalcedony after gypsum and aragonite (*Figure 11, 12*).

In some instances, pseudomorphism



Figure 7. Marcasite plumage in agate nodule from Cathedral Mountain Area, west Texas. The plumage has a thin coating of Red Hematite. X2.



Figure 9. Agate pseudomorph after aragonite in agate nodule from Lake Superior Region, Minnesota. X3.



Figure 11. Partial pseudomorph of chalcedony after Gypsum, from Oligocene, Chadron Formation, Crawford, Nebraska. Note that the chalcedony retains the Gypsum cleavage. X1.



Figure 8. Sagenitic growths in agate nodule from Ojo de Laguna, Chihuahua, Mexico. Radial, needle like crystals in upper left are aragonite. Coarse crystals in lower right are siderite, probably pseudomorphous after aragonite. X1.



Figure 10. Goethite needles in agate nodule from Ojo de Laguna, Chihuahua, Mexico. Note that the needles form nuclei about which eyes and tubes precipitate. X0.5.



Figure 12. Onyx probably pseudomorph of chalcedony after Gypsum, from late Precambrian, Lake Superior Region, Minnesota. X2.



Figure 13. Latex cast of prismatic barite crystal mold in agate from Late Precambrian, Lake Superior Region, Minnesota. X1.



Figure 14. Stalk-like aggregates in agate nodule from Botswana, Africa. Note the plastic deformation of the banded portion of the agate. X1.5.



Figure 15. Globular-collimorphic texture in lace type agate from near Ojo de Laguna, Chihuahua, Mexico. X0.7.



Figure 16. Spherulitic, limonite pisolites in agate nodule from Moctezuma, Chihuahua, Mexico. X1.5.



Figure 17. Chromatograph in agate nodule from Moctezuma, Chihuahua, Mexico. X1.7.

of a slightly-soluble crystalline inclusion does not take place after the inclusion has been dissolved. This leaves a crystal mold, a structure that is fairly common in geologically old agates but rare in young agates. Many of the crystals in young agates probably have not been given sufficient time to dissolve away by weathering processes. Latex casts have been made of some of these molds (*Figure 13*) and most appear to have housed prismatic barite or scalenohedral calcite crystals.

Stalk-Like Aggregates

Stalk aggregates (Lebedev, 1967, p. 59-60) are fairly common inclusions in agate. Like stalagmites in caves, stalk aggregates grow in a direction opposite to the movement of particles in solution. In other words, the aggregates are oriented upward although they appear stalactitic. These probably form when droplets of a less dense liquid (water?) rises toward the top of an unsolidified silica gel. Stalks may, in some cases, deform the banding of an agate (*Figure 14*). All of the stalks have identical orientations. They are common to most types of agates studied. These have been duplicated in the laboratory by upward movement of small quantities of water through bromoform (S. G. = 2.85).

Oolites and Pisolites

Oolites are spherical mineral aggregates characterized by a distinct, concentrically zoned structure. Oolites greater than 2 mm in diameter are conventionally referred to as pisolites. They are generally spherical, growing

about a central nucleus, but they may develop irregular structures such as ellipses or may become polyhedral, with distinct faces upon close compaction (see Lebedev, 1967, p. 18-24). Oolites and pisolites grow by accumulation of material on their outer surfaces. Oolites and pisolites require a fairly high energy environment to develop. Since they grow by external accretion, their presence suggests the cavity in which the agate developed was periodically invaded by moving, mineralized water before the agate formed. Chalcedony pisolites probably grow in the same fashion and are one case where agate actually developed by successive deposition of layers of silica, but from inside out instead of outside in. Pisolites in nodular agates are normally engulfed in chalcedony. Lebedev (1967, p. 26-33) described five oolitic-pisolitic textures, two of which have been recognized in agates. The globular-collimorphic texture appears to be common in the lace-type agates from northern Mexico (*Figure 15*). The lace-type agates normally form in open veins rather than in closed vesicles; thus, accumulation of agate by layers takes place in this situation.

Agates containing spherulitic textured pisolites are common in the Tertiary basalts of west Texas and from the Moctezuma region in Chihuahua, Mexico. Pisolites are rare in the Late Precambrian agates from the Lake Superior region. Pisolites may be of calcite, limonite (*Figure 16*), or chalcedony, the latter usually being pseudomorphic after the former two.

Some pisolitic structures have been

referred to as algal in origin, probably based on Elias' (1931) interpretation of pisolitic limestone in Wallace County, Kansas. Swineford *et al.* (1956, p. 98-116) have demonstrated that pisolitic limestone developed as a result of soil forming processes. They indicated that conditions favoring development of pisolitic limestones were (1) rocks containing easily soluble minerals giving residues rich in Ca^{2+} ion; (2) effective rock permeability; (3) deficient rainfall and long, dry periods; (4) low topographic relief; (5) time. Three of these conditions would occur in a basaltic flow where plagioclase could furnish Ca^{2+} ion, permeability is high, and topographic relief is generally low. Water supply is controlled in climate.

Chromatographs

Chromatography occurs when mixed dyes are separated by a porous membrane. The particle size of the dyeing agent controls this process — the larger particles first being trapped and finally the smaller. Chromatographs have been observed only in the Tertiary age agates from northern Mexico (*Figure 17*). The spherulitic chalcedony crystals function as the membrane and metallic salts are distributed throughout the bands. The available space between spherulitic crystal clusters forming the bands controls which coloring agents are deposited where in the nodule. The presence of chromatographs suggests that coloring is a post-genetic feature in agate nodules.

Conclusions

Some of the above explanations of the structure of and inclusions in agates vary considerable from earlier ideas. The results of this research show that most agate nodules have many similar features regardless of age or origin.

Pre-genetic inclusions in agate, such as aragonite crystals, are usually unaltered in geologically young agates but frequently replaced by chalcedony pseudomorphs in geologically old agates. Plumes are common in young agates and rare in old agates. Crystal molds, are conversely, rare in young agates and common in old. The presence of low-temperature crystalline inclusions and pisolites suggests that agate is a low temperature-pressure product of weathering and soil development. The absence of hydrothermal sources in the area of abundant Tertiary agate occurrences off west Texas and northwestern Nebraska are further evidence that agate forms at low temperatures and pressures.

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Book Reviews

GEMSTONES FOR EVERYMAN, by Basil W. Anderson. Published by Van Nostrand Reinhold Co., New York, 1976. Illustrated in black and white and color. 368 pages. Hardbound. Price: \$25.00.

It is a pleasant experience to encounter a book on gemstones that is written by a person eminently qualified to do so based on knowledge and experience and who also writes in an easy-to-read style. B. W. Anderson, the founder and long time leader of the famous London Gem Testing Laboratory, with the ringing title, "The Precious Stone and Pearl Laboratory of the London Chamber of Commerce and Industry," is such a person. The author of *Gem Testing*, now in its eighth edition, and lecturer for many years for the Gemmological Association of Great Britain, is still, in retirement, preparing and grading diploma examinations for the Gemmological Association. There is no one with more knowledge or experience with gemstones than Basil Anderson.

Many of the so-called popular books or picture books related to gemstones talk down to the reader, and seemingly are written for ten year olds. This book does not, in any way, talk down to the reader; in fact, some

rather technical items are covered, but they are covered with such clarity that anyone could find them interesting. One example of the type of high level information that is covered so lucidly is the reason why the fluorine-rich topaz has lower refractive indices than the fluorine-poor material.

There are over three hundred pages, and a rather small type face allows the publisher to get 40 lines to the page, so there is an enormous amount of information crammed into "Gemstones for Everyman." In our opinion, it makes just as interesting and rewarding reading for the experienced gemologist as for the novice. This is a very worthwhile addition to every person's library.

JEWELER'S DICTIONARY 3rd EDITION, Edited by Donald S. McNeil, Published by Jewelers Circular-Keystone, 1976. Illustrated in black and white. 268 pages. Hardbound. Price: \$39.95.

The Third Edition of the "Jeweler's Dictionary" published by *Jewelers' Circular-Keystone* is now available. It has been very painstakingly revised as it was brought up to date by the retired editor of *Jewelers' Circular-Keystone*, Donald S. McNeil.

The new edition of the dictionary would seem to be a must for every jeweler's library in that it is an up-to-date edition of a work that has been out of print for many years. There is no more painstaking or careful editor than Don McNeil and the book is much more valuable than the second edition because it is not only carefully edited and greatly enlarged over the last edition, but it is very effectively illustrated as well. There are a large number of half tones in the book, and in addition, many excellent line drawings. There is little to criticize about the book except for its \$39.95 price tag. A book of this sort is exceedingly valuable if thoroughly researched and up to date as is this work, but the price does seem a bit difficult to justify. We still recommend it as a very valuable edition to the retail or wholesale jeweler's library.

PRACTICAL GEM TESTING by David Lewis, F.G.A. Published by the N.A.G. Press Limited, London, 1977. Illustrated in black and white. 149 pages. Hardbound. Price 7 pounds 50.

"Practical Gem Testing" as stated by the author, David Lewis, F.G.A. is not intended "as a work to advance the science of Gemology, but as one to make Gemstone Identification available to a wider group of people." He further states "The purpose of this handbook is to provide guidance to the reader who wishes to identify the most commonly encountered gemstones in the quickest and surest manner." The book is designed as a guide for the identification of jewelry-

set gemstones where light can be transmitted through the stone and the gem can be tested on the refractometer.

The general layout of the book is new and interesting. Mr. Lewis takes us in the first 42 pages through a brief, but essentially well done section on gem testing instruments and techniques.

The second half of the book is devoted to gemstone identification. The gem materials in this section are listed in alphabetical order and a numbered sequence of tests is given intended to lead to positive identification of that gemstone.

The book, however, in spite of its unique format, contains a few errors and omissions that should be noted. In the section on gem testing instruments and techniques the reader is asked to look at a diagram when the distant vision (spot method) of refractometry on cabochons is being discussed. The diagram illustrated is not an example of the image seen when taking a refractive index on a gem with a curved surface. Under the sections on the use of the polariscope and refractometer, and throughout the entire text, no credence is given to the value of optic character (figure and sign) in the testing of mounted gemstones.

In part two, identification of gemstones, the water drop test as a means of separating diamond from its substitutes is discussed. It is stated that the test is related to hardness and that a drop of water will "spread out to cover more of the surface of a soft stone than a hard one." It will be found, however, by careful experimentation that the major diamond substi-

tutes are more hydrophobic than diamond.

Apatite is said to show movement of both shadow edges when tested on the refractometer, which is in direct conflict to its uniaxiality. In addition the spectrum of yellow and green apatite is attributed to didymium "a rare earth element," which is in fact a mixture of rare earths.

Zircon is not broken down into high, medium, and low types, and the generalized statement, "the birefringence of the zircon is so great," does not take into consideration the metamict, nearly amorphous low zircon. Between apatite and zircon there are other small errors. In addition the tables in the appendix will find limited use, and the book contains no bibliography. In spite of the aforementioned drawbacks the book has several redeeming qualities. The black and white photographic illustrations of inclusions are very good. The clear and concise manner in which Mr. Lewis describes testing methods, like the copper sulfate filtering technique in spectroscopy and the crossed filter test, is helpful. The layout of the book, with its step by step gem testing procedures, is unique among gem testing handbooks and should make a welcome addition to the gemologist's reference library.

HOW TO FIND AND IDENTIFY THE VALUABLE METALS by George F. Muns. Published by Dorrance and Company Incorporated, Ardmore, Pennsylvania. Illustrated in black and white. 133 pages. Hardbound. Price: \$6.95.

The new book "How to Find and Identify the Valuable Metals," by George F. Muns, is very well written, easily understood, and accurate in its content.

In the book, the crystal systems are briefly described, and the individual metals are discussed in the order of their grouping in the periodic table. A great deal of information is contained in this section on the metals and metal groups such as abundance in the earth's crust, uses to which they are put, relative stability, and so on.

The most extensive section in the book describes a series of systematic chemical tests that can be carried out to correctly identify the presence of any one of the major mineral forming metals. This section is especially useful to exploration geologists and mineralogists who might desire a confirmatory test that can be performed in the field for a particular mineral that has been tentatively identified.

The book concludes with appendices of elements, chemical reagents, laboratory equipment and suppliers, a brief glossary of terms, and a bibliography.

This book is recommended to anyone with an amateur or professional interest in metals, metalliferous compounds and mineral exploration.

GEMSTONES OF THE WORLD by Walter Schumann. Published by Sterling Publishing Company, Inc., New York, 1977. Illustrated in Color and Black and White. 256 Pages. Hardbound. Price \$12.95. First published in Germany, and then translated into

English by Evelyne Stern, F.G.A., for the NAG Press in London.

"Gemstones of the World" has some of the most beautiful illustrations of any book we have encountered, and is particularly useful for those who are looking for good illustrations of the unusual stones. There are good photographs of a wide variety of the rarely encountered collector's gemstones. For the most part, the information in the book is accurate and useful. It does not pretend to be a real text book, and in some sections, it is less than up-to-date. For example, ruby is listed as being found in Burma, Thailand, Sri Lanka and Tanzania, and that from Tanzania is listed primarily as the opaque ruby and ziosite, plus a few items from the Umba River. No reference is made to rubies from Kenya, for example. Similar comments could be made about some of the other information on the important colored stones. However, the book is very useful in that it has extensive tables and the aforementioned excellent color plates. Dr. Schumann has his tables divided in a very interesting fashion in that he separates by color, e.g., violet plus blue-red, divides them into columns vertically that show R.I.'s from 1.4 to 1.499, 1.5 to 1.599, etc., and then separates horizontally on the basis of specific gravity in rather broad categories. After the name of singly refracting stones, he

lists the hardness, and after those that are doubly refractive, he lists hardness and birefringence. Refractive Index and specific gravity are not shown individually in these tables, but they do show an interesting arrangement, which would be of some assistance in identification.

SCHEDULE OF ORNAMENTAL AND GEMSTONES by Dieter Pschichholz, F.G.A. Published by Ruhle-Deibener Publishing Company, Stuttgart Germany. Illustrated in color. 65 pages. Loose Leaf. Price: not known.

In his tables Mr. Pschichholz, with only a few omissions, has put together a rather complete listing of both the more commonly encountered gemstones and the very rare collector's gem materials. The tables are ordered vertically with increasing refractive index, and the information on individual gems is laid out in a horizontal direction.

There are omissions in the tables of information that could have been easily added to make these tables more complete and useful. There are also some areas where the information is somewhat misleading, such as for Malachite where the range of refractive index given is considerably less than the actual mineral shows. The color drawings of absorption spectroscopy findings could also mislead the user as to what to expect.