Gems & Gemology

GIA

FALL, 1972

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A Quarter Century of Diamond Research

BY
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Although diamonds had been used in relatively simple industrial applications before the outbreak of World War II, it was the war that hastened man's dependence on the industrial diamond as an essential mass production tool. The fabrication of harder metal alloys, carbides and ceramics, which became increasingly difficult to grind and machine, demanded the toughest of all abrasives and only diamond was tough enough to cope.

Now, while it is a comparatively simple matter to define a good rough gem diamond in terms of color, size and freedom from visible impurities or other blemishes, the criteria of a good industrial diamond and the knowledge and skill required to use it to the best advantage, either as a single stone or in the shape of fragmented particles, are more complex and more directly related to the basic properties of the diamond.

It was to investigate these basic properties and to solve the problems associated with applying them efficiently for the benefit of industrial diamond users that Sir Ernest Oppenheimer, then chairman of De Beers, established the Diamond Research Laboratory.

When the Laboratory celebrated its 25th anniversary in July, 1972, it was appropriate that Harry Oppenheimer, present chairman of De Beers, should be guest of honor at a function which commemorated the laying of the foundation stone by his father on April 21st, 1947. Three months later, to the applause of the 17 members of the original staff who occupied the small single-story building which had just been completed, Sir Ernest said:

"It is our object to study industrial diamonds and, in cooperation with producers, consumers and scientific bodies all over the world, to find improved and new uses for them in industry. In this age of mechanical progress industrial diamonds have achieved the status of a strategic material for which there is no substitute.

"No great industry can exist or develop without comprehensive research and I firmly believe that the establishment of this laboratory will be to the benefit of all those directly or indirectly concerned with diamonds."

It is a peculiarity of science that though short-term problems are continually being faced and solved, the essential objectives remain constant, and the objectives voiced by Sir Ernest – 25 years ago – are hardly any different today. The biggest change, of course, is one of dimension. From the simple little brick structure which looked almost incongruous in one corner of a vast 9-acre site, has grown a complex of six impressive modern laboratory buildings, totalling 137,000 square feet in extent, in which 350 people are engaged day in and day out on research into just one material – diamond.

This, indeed, was and always will be one of the Diamond Research Laboratory's biggest problems. In the normal diverse research establishment, a limited number of techniques is used in the study of many materials. The research philosophy at the Diamond Research Laboratory – the study of one material with the widest possible range of techniques – involves a great diversity of expensive equipment and a need for scientists and engineers who are experts in many specialized fields.

When it was established, the D.R.L., as it is known colloquially, was the only laboratory in the world devoted exclusively to diamond research. Since then, similar institutions have been set up in the United States and in Russia. But the D.R.L. is still the biggest.

Special Research Project

Right at the outset, valuable fundamental work was done in Johannesburg, based more upon the availability of large supplies of diamonds of every conceivable variety, than upon a study in depth of any particular property of diamond. But, it became obvious that this new laboratory would not, on its own, be able to cover adequately the

WHERE IT ALL BEGINS – The De Beers Diamond Research Laboratory has grown from a one-story building 25 years ago to the complex seen here.

surprisingly intricate and involved study required. Thus, Sir Francis Simon, later the Clarendon Professor of Physics at Oxford University, was asked to gather a team of eminent overseas scientists together for the purpose of studying diamond problems. This was the birth of the Special Research Project which today, more than ever, is helping De Beers to uncover the secrets locked in that complex crystal – the diamond.

When the Special Research Project was initiated, only the fundamental properties of diamond – its strength, hardness and thermal conductivity – were known. A major achievement of these scientists, sponsored by and working with De Beers, was the publication, in 1965, of the only authoritative book written on the physics of diamond. Entitled simply *"Physical Properties of Diamond,"* the book contains a vast amount of information on diamond's crystallography, its mechanical, electrical, thermal and optical properties, and the effect on its properties of radiation damage.

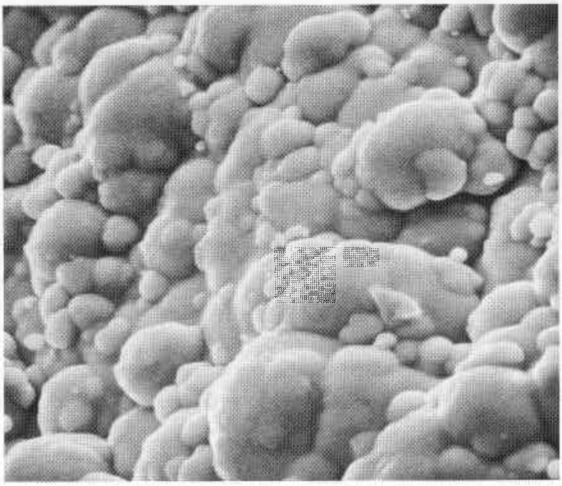
The name of the book's editor, Dr. R. Berman, is familiar to all students of diamond for it was he, in partnership with Sir Francis Simon, who calculated the Berman-Simon Equilibrium Line which represents graphically the pressure and temperature conditions under which diamond can be synthesized.

Tailor-Made for the Trade

Diamond synthesis, which was successfully achieved on a laboratory scale in 1955 by the General Electric Company of America, posed a tremendous challenge to the D.R.L. Such was the strategic value of industrial diamond at the time that the U.S. Government placed a strict embargo on the publication of information about synthesis. Hence the South African team, assembled in 1956, had to go it alone. After partial success in 1958, the Adamant Laboratory, set up as an ancillary laboratory of the D.R.L., was able to announce the production of synthetic diamond on a commercial scale in 1959.

World industry, which had begun to consume diamond at a rate which threatened to outstrip availability, now had two sources of supply and two distinct types of diamond abrasive to choose from – synthetic and natural. Although specialization in the natural diamond grits had been introduced by De Beers a few years earlier – strong, blocky particles for grinding wheels manufactured by the metal bond process and more elongated friable particles for resin bond grinding wheels – synthesis can be said to have laid the foundation stone for the proliferation which followed.

Today, diamond abrasive is virtually tailor-made – either by synthesis or by mechanical processing – for every conceivable application. De Beers alone markets 16 stock types and numerous other "specials" and each has been invented, developed, tested and finally piloted to production by the D.R.L., which also plays the part of policeman to the



A UNIQUE "COAT" – This electron micrograph shows coating on a single diamond grit

production plants, continually scrutinizing, sampling and otherwise quality controlling the diamond destined for world markets.

Fortunately for industrial diamond consumers, whose appetite increases at the rate of 10% per annum (in 1971 it was not far short of 60 million carats) the synethetic product has supplemented natural-mined diamond; so the historical fear that supplies would dry up is now a thing of the past.

The processing of diamond, to the stage where it can be marketed as a finished product, is much more complicated than it sounds. For one thing, the sources of natural diamond are varied, originating from alluvial diggings or pipe mines in many different countries, and the synthesis processes are equally varied, being designed to produce an infinite range of qualities, shapes and sizes. In the second place, the market requirement, in terms of shape, strength, size, crystallinity, quality and color, are as varied as the uses to which diamond particles can be put.

Making the Machinery

Most of the very specialized machines used by De Beers to carry out the function of grading and processing were invented and developed by the D.R.L. As can readily be appreciated, the method of operation of many of these devices is secret; but two which have become standard equipment in the diamond business are the shape sorting table and the Friatester. The shape sorter is an electrically-vibrated metal table which can be adjusted to various angles, with from 12 – 14 receptacles or bins attached to its lowest side. The diamond particles to be sorted according to shape are fed onto the deck from a glass container on the opposite side of the table. When the electrical current is switched on, the table vibrates at a predetermined frequency. The vibrations cause the roundest or blockiest shapes to roll quickly into the bin at the bottom end and the others to bounce their way into different bins higher up on the table. Because they are the least able to roll, the flattest and most needle-shaped particles travel to the highest bin. This method, the most ingenious ever devised for sorting shapes, is now a production process, but it is also used continuously at the D.R.L. as a control check and for experimental work connected with the development of new diamond products.

The Friatester was designed and built, and has been modified many times, at the Laboratory. In its present form, it is a highly sophisticated electronic device for measuring rapidly and accurately the strength of any kind of diamond abrasive and its resistance to impact. It imparts to the grit particles a strictly controlled form of comminution for a predetermined time, after which readings are taken. The measure of strength, referred to as the Friatest Index, or F.I., is defined as the number of cycles required to reduce a specified quantity of the grit to 50% of its original weight of on-size material, when the machine is run at a certain number of revolutions. Infinite accuracy is the keynote of the Friatester, which gives readings to four decimal points.

One of the most dramatic developments in grit processing has been the introduction of metal clad diamonds. Years of research proved that the jacketing of diamond particles with a continuous metal coat – sometimes nickel, sometimes copper or sometimes a composite of several metals – would improve the keying of the particle in the bond of a grinding wheel, since metal adheres more readily to resin than does diamond. Furthermore, it was shown that the metal coat served to retain the fractured particles of diamond, thereby prolonging the life of the grinding wheel. Finally, it was reasoned, and proved, that the metal, being a slower thermal conductor than diamond, would slow down the transmission of heat from the point of contact between the grinding wheel and the material being ground, thus avoiding charring of the bond. All things being equal, a grinding wheel containing metal clad diamond, lasts more than twice as long as a wheel containing unclad diamond.

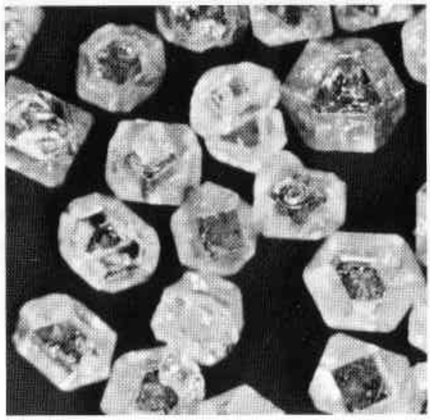
New Fields to Conquer

The D.R.L. introduced a new concept in its endeavors to find "improved and new uses for diamond grit" – in accordance with Sir Ernest Oppenheimer's wishes – when it set up a grinding center. Initially a research tool for testing grit products, it was extended in scope to provide a service to diamond grinding wheel manufacturers by helping them to optimize the conditions under which diamond would grind more efficiently than any other abrasive.

One of the grinding center's most far-reaching achievements was the discovery that a new grit which the Laboratory had developed would grind steel more economically than did the conventional types of abrasive – aluminum oxide and silicon carbide. The range of successful applications is not complete, but for some hard-to-grind steels the economic threshold has been passed and diamond is, or should be, the preferred abrasive.

While DXDA-MC – the name given to the metal clad diamond abrasive developed by the D.R.L. specifically for steel grinding – is greatly superior in grinding efficiency to conventional abrasives, diamond grinding may still appear, on the face of it, to be a more expensive way of machining because of the high intrinsic cost. However, there are often unexpected advantages which may far outweigh small differences in the actual cost of machining. Typical of these is the strengthening of the physical properties of the steel being ground. In a test where ground specimens were subjected to repeated tensile stresses, the pieces of steel that had been ground with aluminum oxide failed at 200,000 cycles; those ground with diamond were still intact after 7,500,000 cycles.

A similar service is extended by the Diamond Research Laboratory to the manufacturers and users of diamond saw blades. Apart from evaluating the performance of De Beers own saw abrasives, the well-equipped saw bay cuts up rock of various compositions and hardnesses in order to assess the optimum wear rate under such saw blade parameters as diamond grit size, diamond concentration, diameter of blade, etc., and machine parameters like peripheral speed of the saw, infeed rate, depth of cut and volume of coolant.



SDA100 is a superior synthetic diamond abrasive used for sawing applications.

In recent years, there has been an upsurge of diamond usage in the building and construction industry. To encourage this demand the D.R.L. has set up its own concrete casting department which supplies reinforced concrete slabs to the saw bay. These are cut under the same carefully controlled conditions and the saw bay's findings are communicated to blade manufacturers and concrete sawing contractors all over the world. The success or failure of diamond products in these areas is greatly dependent upon the D.R.L.'s understanding of the technical nature of the problems involved.

Turning to diamonds whose shape and surface characteristics are visible to the naked eye, the users of diamond drill crowns will remember a serious shortage of good drilling material in the late 1950's. D.R.L. scientists – in cooperation with major drilling companies throughout the world – evolved a processed form of drilling diamond that could be guaranteed to give reproducible results. The end product, Hardcore, freed the industry from the shackles of a particle size distribution imposed by nature and allowed the diamond drill manufacturer to choose the size of diamond appropriate for the job and not just that which was available.

The D.R.L. has a department for testing diamond drill crowns in much the same way that the grinding center and the saw bay test wheels and saws. This department, too, after long involvement with rock drilling – an essential adjunct to mining – has now turned its attention to the building and construction industry where diamond has wide usage and even wider potential.

Diamond Types

But the hurly burly of producing, testing and proving better diamonds for industrial application is far from being the only activity of the D.R.L. On a more fundamental plane, the separation of diamonds into distinct, recognizable types was one of the earlier subjects of research at the Laboratory. For example, it was first shown that diamonds could be divided into two main categories, Type I and Type II, of which diamonds of Type I are by far the most common. This type contains up to 0.2% of nitrogen, mainly in the form of precipitates, whereas Type II diamonds contain nitrogen in negligible quantities and are therefore purer. A rare natural form of Type I diamond was then discovered at the Laboratory. In these diamonds the nitrogen is included in the form of single substitutional atoms and not in platelets as is the case with the majority, which the D.R.L. then classified Type Ia, reserving the classification Ib for the rarer type containing dispersed nitrogen.

It was once believed that all diamonds occurring in nature were perfect electrical insulators. This was disproved at the D.R.L. when two gem diamonds in a sample of concentrates failed to respond to electrostatic separation (a method developed by the Laboratory to separate diamonds from other heavy minerals in mined concentrates). Further investigation showed that these diamonds, of Type II variety, possessed a hitherto unknown property of semiconduction and were capable of rectifying electric current passed through them. This called for a further subdivision into Type IIa, the good insulators, and Type IIb, the semiconductors. The D.R.L. found that the electrical resistance of Type IIb diamonds was highly sensitive to changes in temperature. Linked with electrical measuring apparatus, these diamonds detect and record changes in temperature as small as one five-hundredth of a degree centigrade, making them suitable for medical instruments and in industries where the accurate and rapid monitoring of temperature is of vital importance. Type IIb diamonds are also incorporated in space satellites for measuring temperature conditions in space.

Type II diamonds of gem quality have a thermal conductivity, at room temperature, very much greater than any other solid. They are therefore finding increasing use as heat sinks in a wide range of semiconductor devices, where the dissipation of heat is a serious problem. In the past, heat sinks have generally been made of copper but miniaturization demands smaller and more efficient heat dissipation. The use of a diamond as the heat sink in one particular electronic device has made it possible to increase power output from 2 watts to 15 watts without it being necessary to increase the physical size of the device.

Color, Quality and Hardness

Because the color of diamond is of great interest, not only to pure scientists but also to the gem industry, it has been studied extensively at the D.R.L. Pure, perfect diamond is colorless since it does not absorb light in the visible spectrum. Some Type IIa diamonds fall into this category, although the majority exhibit a brownish color. The color of the Type I diamond is dependent on the mode of inclusion of nitrogen, some being colorless (because they absorb light only in the ultraviolet region of the spectrum) and others being yellow or greenish yellow.

One of the methods used by scientists at the D.R.L. to study defects in diamonds has been the deliberate inducement of defects by irradiation. The instrument used to accomplish this is a 2 million volt electron accelerator (now being operated at the University of the Witwatersrand, in Johannesburg, on De Beers' behalf), in which diamonds are bombarded with electrons. The principal effect is to change the color of the diamond, though the color change is usually only skin-deep. Neutron bombardment effects a more drastic color change which pervades the whole diamond. Controlled heating of certain electron-irradiated diamonds in diffused light induces a further color change but when these diamonds (so-called chameleon diamonds) are exposed to sunlight they revert to their original color. This work, while providing a better understanding of diamond physics, clearly established that the artificial coloration of diamonds by irradiation cannot change a brown or yellow stone to white; nor can it make a bad diamond into a good one.

Further research into the mechanical properties of diamond verified that all diamonds have what is called a "hard" direction and a "soft" direction. This fact, long recognized by diamond cutters, is of great importance in engineering applications because even slight changes in the orientation of a diamond lead to a marked reduction in abrasion hardness. Proper orientation has increased the wear resistance of a tool by as much as 240% and some years ago the D.R.L. developed an X-ray image intensifier method to orient diamonds rapidly and unambiguously.

So important is diamond in engineering operations that much of the work being done today, by scientists at the D.R.L. and its sponsored university teams, is connected with the mechanical properties of diamond. The studies include the effect of parameters such as orientation, strain and inclusions on the behavior of single point diamond tools, and the friction between diamond and a variety of workpieces in different environments. Another of the projects holds considerable interest for the gem diamond trade. For some time jewelers and gemologists have been discontented with the exploitation of the Mohs hardness scale by the advertisers . . . of YAG (yttrium aluminium garnet) synthetic spinel and other diamond imitations. This outmoded scale, which merely lists a number of materials in *order* of hardness, has been quoted time and time again, somewhat unfairly, to show an apparently small difference between diamond (10 on the Mohs scale) and the imitations (between 8 and 9). A graph drawn of the relative hardness of materials listed on the Mohs scale takes a steep upward curve between 8 and 10 so that, in fact, the difference is infinitely wider than is claimed by advertisers of the manufactured imitations. Consequently these are indented or scratched many times more readily than is a diamond. To assist the jewelers to refute exaggerated claims, the D.R.L. has initiated a full-scale program at Exeter University in the United Kingdom. The scientifically based hardness scale which will emerge is to be widely publicized and will do much to place the YAG's and the Lasalites and all the other imitations in their true perspective.

Service to the Mines

The part played by the D.R.L. in facilitating the processes of mining and recovery is incalculable. One of the most important functions of the Laboratory since its inception has been to provide technical assistance and advice to the diamond producers. Down the years this has included the invention of new processes and the refinement of old ones. It has included the design and construction of pilot plants, their testing in the Laboratory and *in situ* and ultimately their commissioning as fully-fledged production units. It includes, too, the full-time secondment of senior technical officers from the D.R.L. to various mines and today it is not unusual on any given day to find more than half the personnel of the Laboratory's Mines Division in the field.

In many ways diamond mining is quite unlike any other kind of mining. To start with, the diamond must be recovered undamaged from its ore; its presence in the ground cannot be determined by chemical assay methods, as is the case with most minerals; and the end product, though small in size, is many times more valuable, weight for weight, than any other mineral. This means that diamond mines can afford to treat a ratio of waste material to end product that would be quite unthinkable on any other mine. The ratio is as high as one hundred million parts of waste to one part of diamond at Consolidated Diamond Mines. In the richest Kimberlite it is between 15 and 20 million to one.

Getting the diamonds out of the ground and into the sorthouse more quickly, more efficiently – and therefore more cheaply – has always been the concern of the mining and metallurgical division of the D.R.L. Research was started as early as 1947, the year the Laboratory was opened, into a method of separation based on the fact that nearly all diamonds are poor conductors of electricity. This method, known as electrostatic separation, proved very effective for the treatment of alluvial gravels, especially the heavy gravel from the marine terrace deposits in South West Africa. The electrostatic method was also introduced at various pipe mines to simplify the recovery of diamonds smaller than 10 U.S. mesh.

The secondary recovery of diamonds usually involves some form of grease adherence. Even before the turn of the century it had been observed that diamonds adhered firmly to grease whereas many of the minerals found in association with it did not. Diamonds repel water and this "nonwettable" characteristic led to the early development of the grease table, which involves washing the final concentrates over a series of angled surfaces thickly smeared with grease. Many alluvial diamonds have developed a molecular skin of mineral salts and thus lose their tendency to repel water. Because of this, grease tables were largely ineffective at Consolidated Diamond Mines and the D.R.L. was commissioned to solve the problem. The Laboratory devised a method of chemically conditioning the diamond concentrates with a reagent which restored a nonwettable surface to the diamonds, and then designed the grease belt, a quicker and more efficient grease recovery method than the grease table. Grease belts have replaced grease tables at almost all the De Beers mines in South Africa, including the central treatment plant at Kimberley which serves the three producing pipe mines in that area.

For the purpose of checking the efficiency of grease recovery and electrostatic separators, the D.R.L. invented a new machine which was based on the principles of light transmission, reflection and scatter by the diamond when it passes through a sharply focused narrow beam of visible light. The light impulse from the diamond is picked up by a photomultiplier, whose amplified signal is made to trigger a gate that diverts the diamond from the stream of gravels. This machine serves as an efficient policeman in controlling the recovery efficiency in the treatment plants.

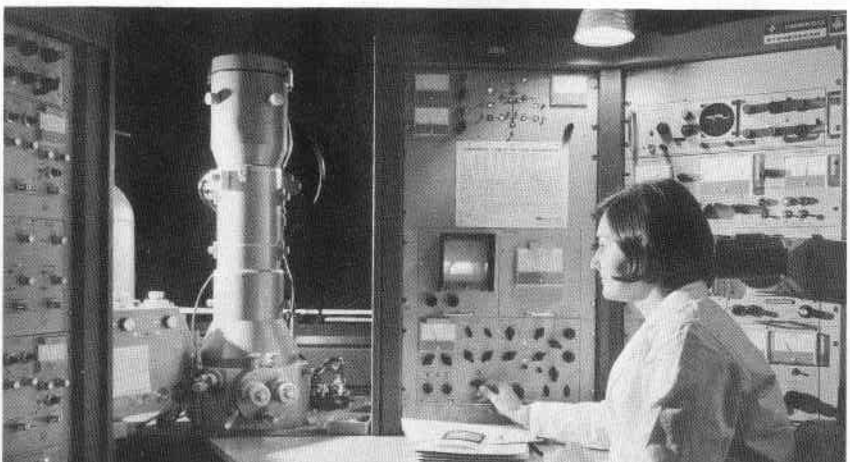
A New Dimension

It became apparent, after 15 years, that test tube and pilot plant experiments at the D.R.L. would no longer solve intricate mining problems and a completely new laboratory – large enough to house full-scale recovery equipment and to handle large tonnages of gravel from the mines – was erected in 1962. The years which followed must rate as the most productive in the Mines

Division's history. Through the development of team expertise, the whole approach towards diamond recovery has been altered and has reached a degree of sophistication undreamed of in earlier days. The final stages of this are now being seen, with the adoption of computer techniques to control recovery plant operation.

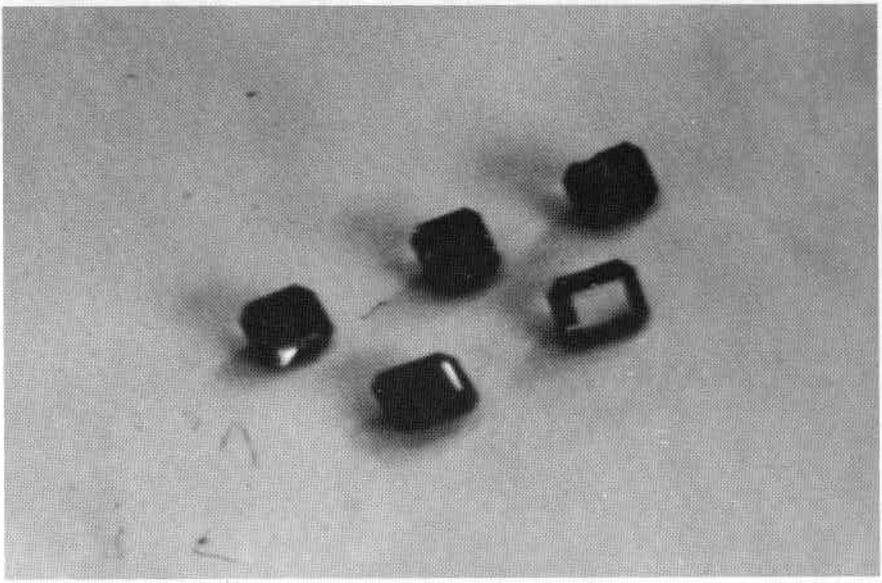
Amongst the most recent innovations, for which the D.R.L. has been responsible, is the X-ray separator which now seems destined to become the successor to the grease belt and grease table. The principle behind the operation of this device employs a property of diamond never before put to use in diamond recovery, namely that a diamond will emit a blue fluorescence when irradiated by X-rays. The concentrates are fed onto a fast-moving belt in the separator and as they move towards the collecting bins they pass through an X-ray beam which causes the diamond to fluoresce. A photo-multiplier detects this fluorescence and activates an air ejector which blows the diamonds out of the trajectory into a separate collecting bin. The efficiency of this machine is extremely high and the concentration ratio the most satisfactory yet achieved. The practical application of these developments can be seen at Orapa Mine in Botswana, which has the most modern diamond recovery plant in the world, a plant which was not only the brainchild of the De Beers Diamond Research Laboratory but was built under the supervision of D.R.L. scientists and technicians and finally commissioned by them.

This involvement in the long-range plans of the diamond industry, as much as in its day-to-day problems, is a justification for the $3,000,000 that is spent annually on maintaining the Laboratory and an indication of how well it is fulfilling the hopes of its founder.



THE STEREOSCAN – This scanning electron microscope is used at the DRL for examining and photographing specimens, with a magnification range from 20 times to 100,000.

Muzo Emerald Mine:



THE END RESULT – These fine Colombian emeralds have total weight of 43 carats, priced at $5,000 per carat, or $215,000.

A Visit

BY
JOSEPH W. TENHAGEN, F.G.A., G.G.
South Miami, Florida

A trip to the Muzo Emerald Mine is really a gemologist's dream come true.

Due to the many difficulties and obstacles involved, I am probably one of the few gemologists in recent times to visit the famous Muzo Emerald Mine in Colombia, South America. Because of government restrictions, it is almost impossible to get permission to enter the area. Only with a letter of authorization from Empressa Colombiana de Minas, "Ecominas," could a venture be attempted.

The difficult drive to the mine began twelve hours late because of various and unavoidable delays. There are only 38 miles of paved highway and approximately 112 miles of very rough unpaved, secondary to barely passable roads. Further, the travel was undertaken in a 1956 Ford station wagon, since newer models in Colombia are very scarce.

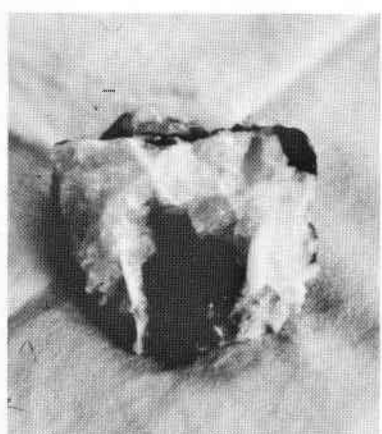
Under such circumstances, other delays were to be expected. We had a flat tire in the village of Chiquinquira and, since it was already late in the day, we spent the night there. The next morning we left Chiquinquira and were even further delayed by an accident two hours or so later when our wagon collided with a large dump

AT THE SITE – This is the Muzo Mine area, with Tequendama bank in center. The principal guard tower is in foreground and there is graded road on top of bank. Dark areas are shale where emeralds are found.

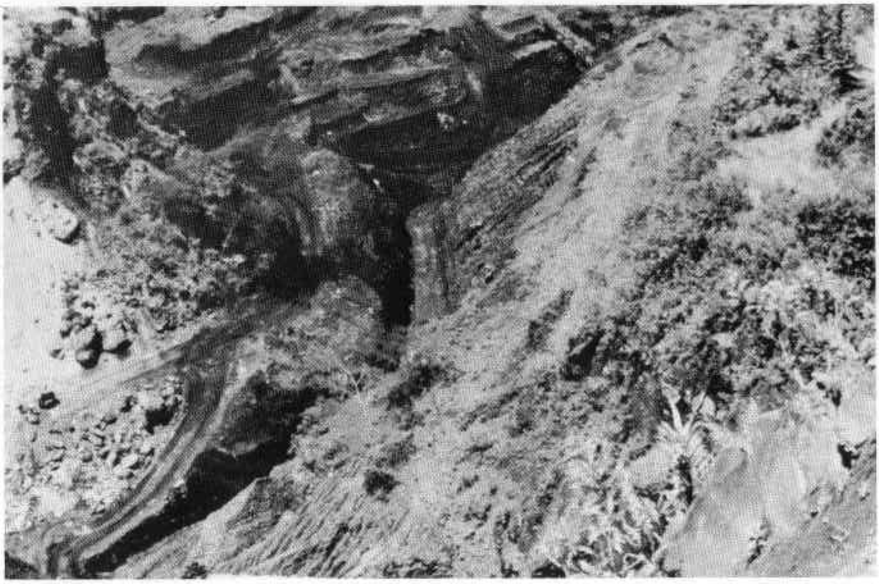
truck on a narrow mountain road. I thought we would never complete our journey.

After seven hours of hard driving, however, we finally completed our journey. Because the entire area is under strict military control, we were stopped six times by army patrols and searched three times. But the hazards of the 55 miles from Chiquinquira to Muzo are overshadowed by the great natural beauty of this rugged country, remaining virtually unmarred by man.

The mine is located in an extremely hot and humid valley, and the surroundings are dense with vegetation. The tour of the mine area was conducted by Senor Oscar Escobar, mine administrator; Luis Bareto, mine superintendent, and four soldiers. The vastness and ruggedness of the mine area was most impressive. The best means of travel is by horseback. Tequendama bank, the term used by the Colombians for the



TYPICAL FINDING – Muzo emeralds typically occur in white calcite and dark shale.



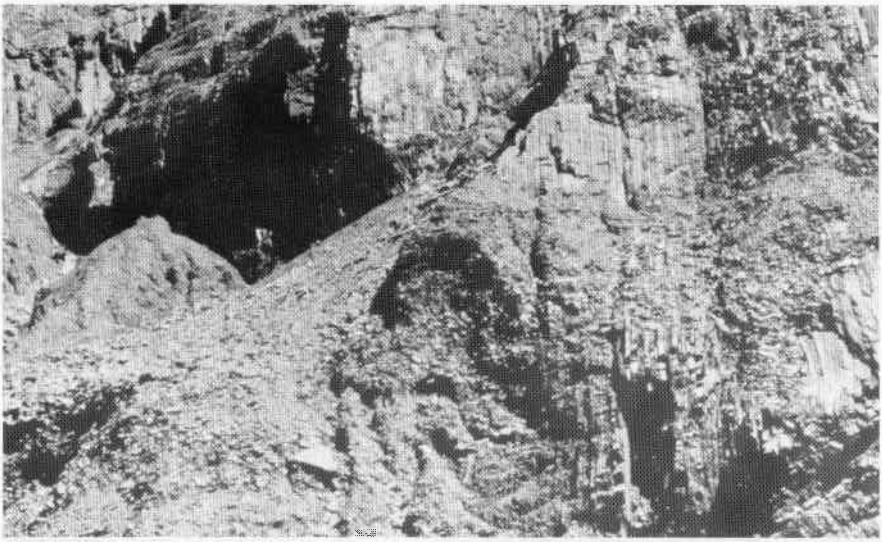
CANAL OF DEATH – Viewed from top of Tequendama bank, this is a highly productive area.

working face, is the most important area for emerald exploitation. This is the same bank (working face) that the Spaniards started working 300 to 500 years ago. Some of the finest emeralds in existence today came from here. At Muzo, there are five or six banks (areas) capable of producing emeralds. Only two are presently being worked. The others will be available for future emerald mining.

The open pit method of mining is used in the two banks presently being worked. Emeralds at Muzo have certain distinguishing characteristics. They occur in white calcite veins situated in a black, sooty carbonaceous shale and limestone. The bedding planes of the shale at Tequendama bank are vertical in some areas and twisted in others due to metamorphism. The emerald-bearing strata is either dynamited or bulldozed, then broken by geology hammers. The emeralds are then picked out of the broken shale. (Only geologists handle the emeralds, the miners do not.)

Water Used

Water is also used in the recovery of emeralds. The emerald-bearing, strata is washed down from Tequendama bank into two canals, or streams. One is the Julio canal and the other is the "death canal," so named because seven poachers have been killed by the guards here in the last several years. The gravel is shoveled out of the stream bed and checked by hand for emeralds. As emeralds are found, they are immediately placed in a double-locked bag carried by the

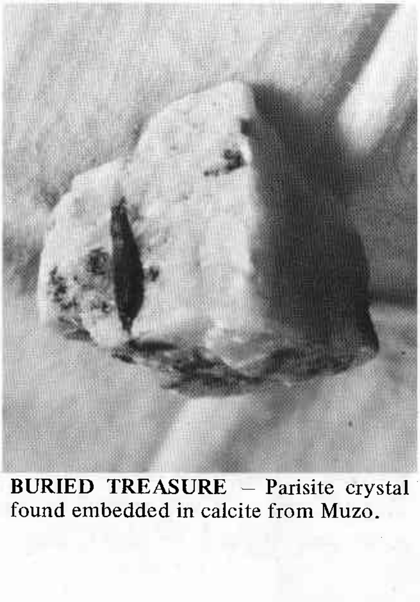


TWISTING AND TURNING – Vertical and twisted bedding planes are shown at Tequendama bank.

geologists. At the end of the day these are taken to the mine encampment and placed under strict security conditions. The rough emeralds are transferred to the "Banco de la Republica" in Bogota by helicopter for ultimate cutting and sale by "Ecominas."

The associated minerals at Muzo are calcite, dolomite, quartz, pyrite, chalcopyrite, barite, limonite, malachite, azurite and parisite, known there as Muzoite. Parisite forms in yellow-brown prismatic crystals terminated by a basal cleavage. It has a chemical composition of [(Ce, La)] F_2CaCO_3 with a refractive index of 1.676 – 1.757, birefringence of 0.081, specific gravity of 4.35 and a hardness of 4 1/2. Muzo is the only emerald mine in the world where parisite is found as an inclusion.

I was most fortunate in obtaining a nice crystal for my collection. The emerald crystals at Muzo are found as hexagonal prisms terminated by a basal pinacoid. Sometimes they are



BURIED TREASURE – Parisite crystal found embedded in calcite from Muzo.

modified by pyramid faces. Emeralds crystallize in the hexagonal system with a chemical composition of $Be_3Al_2(SiO_3)_6$. Muzo emeralds have a refractive index of 1.578 – 1.584, birefringence of 0.006, and a specific gravity of 2.71.

Their color is yellowish-green and they are characterized by their typical three phased inclusions consisting of a liquid, a gas and a solid. These inclusions are generally a flat cavity with a jagged or spiky outline. At Muzo, pyrite is associated with emerald in the calcite, but not found as an inclusion in these stones as they are in Chivor stones. Trapiche emeralds are also found at Muzo.

Tight Security

In addition to the government restrictions and security regulations already mentioned, very tight security measures are also enforced at the mine. There are guard towers stationed throughout equipped with telephones and searchlights. Each station is manned by at least one soldier armed with a rifle. They are manned 24 hours a day, with mounted patrols and police dogs supplementing the guard towers. In spite of all this, a hundred or more poachers a day are ejected from the mine area. They are rounded up like so many cattle, herded into trucks and removed from the immediate area.

This journey is hopefully only one of many more trips to gain further knowledge and insight into the mining, identification and marketing of Colombian emeralds. On my return to Bogota, it was my good fortune to have lunch with Dr. Hugo Canizares, Interventor de Esmeraldas, Ministry of Mines. We discussed the various aspects of the trip and the possibility of future ones. I have since received permission to revisit Muzo in addition to Cozquez, Pinas Blancas and Gachala Emerald Mines.

Also, while in Bogota, I saw a large Trapiche emerald crystal, 1 1/2" by 1" wide. I was fortunate in obtaining one for my collection, a Muzo-type Trapiche which is 12 mm long by 10 mm wide, weighing 10.62 carats.

This trip was an enlightening experience. It was the result of a dream that involved much time, planning and, most important, the efforts of many people. My sincere thanks are extended to Dr. Canizares; Dr. Jaime Gama, Gerente General of Econimas; Senor Oscar Escobar, Muzo mine administrator; and Senor Luis E. Bareto, geologist and Muzo mine superintendent. A special thanks to my good friend, Senor Francisco Farkac, prominent emerald dealer of Dagmar Ltd. at the hotel Tequendama in Bogota. Without their continuous help and support, this trip would not have been possible.

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Developments and Highlights at GIA's Lab in New York

by

ROBERT CROWNINGSHIELD

Television viewers who sat almost on top of their color sets were startled some years back when investigators revealed the possibility of radioactive leakage from those sets.

Evidently, though, that phenomenon isn't solely restricted to television sets – for example, GIA's New York laboratory recently studied a rare, radium-treated green diamond.

In *Figure 1* is shown a beautiful ring set with an approximately 6-carat Lisbon-cut brilliant of an attractive yellow-green color. Under magnification we could see dark spots on the surface indicating radium-bromide treatment. When the stone was tested with a Geiger tube, it registered well above readings we have secured on such things as luminous dial watches. When the stone was placed table down on a bare film for fifteen minutes in the dark and the film developed, an unmistakable darkening was evident. Left on another film over a week-end, the film was completely blackened. These tests indicate that the stone is very highly radioactive – but not so radioactive as to glow in the dark, as has been reported by Robert Webster. *Figure 2* shows some of the surface spots on this diamond. It would seem unwise for the owner of this stone to wear it regularly.

More on Treated Diamonds

Other treated diamonds seen recently in the Laboratory included an

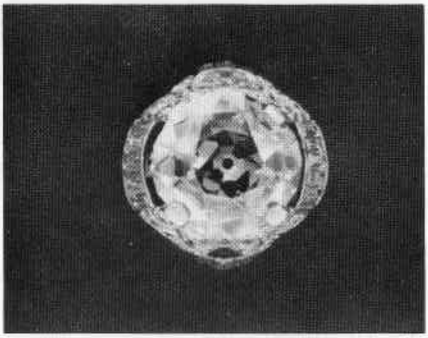

Figure 1

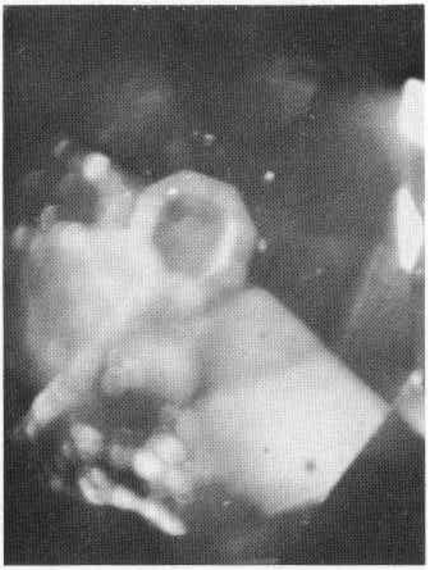

Figure 2

intense-yellow round-brilliant of some 20 carats and a lot of some 50 carats of round-blue brilliants all of the same attractive intense-blue color, somewhat like that of the best fired zircons. The latter diamonds were kindly shown to us by Mr. Harry Neiman, of Nu-Age Products, Hyde Park, Massachusetts, as representative of some of the newer colors his firm can produce.

An Age-Old Problem

One request which the Laboratories have had little success in answering is the matter of identifying so-called grave-old jade. Nephrite which has been buried for long periods of time will alter, becoming, in some cases, chalky or bonelike. Unfortunately, the appearance can be falsified by heat and possibly chemicals. Although curators for collections of old jade must have done research on the problem, we have been unable to find any reference in the literature which will help in determining such altered material. It is definitely, at least on the surface, no longer nephrite. In some cases, it is impossible – with nondestructive tests – to determine if a piece was even nephrite originally.

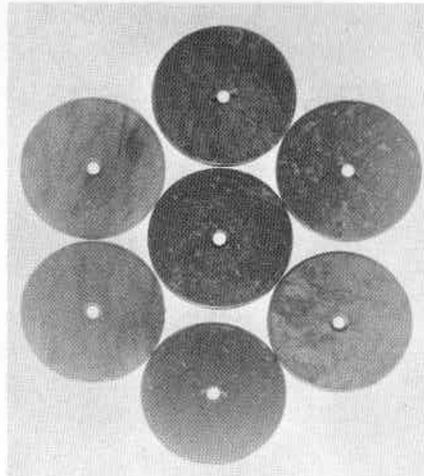

Figure 4

Recently, in a lot of stones given to the GIA, were found a series of drilled-nephrite discs. A few were clearly well polished nephrite, but most appeared to have suffered more or less damage – probably from heat. It was of interest to note that those stones which had suffered damage to the point that the disc was still translucent, but the stone had become brownish in color, showed very distinct absorption lines which have been recorded but are seldom seen in nephrite. The strongest is at 4980Å

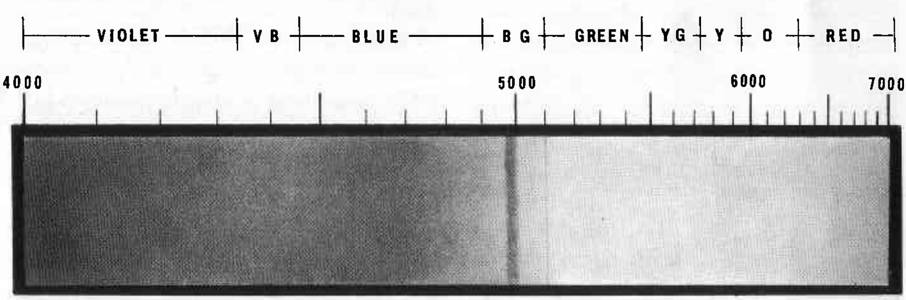

Figure 3

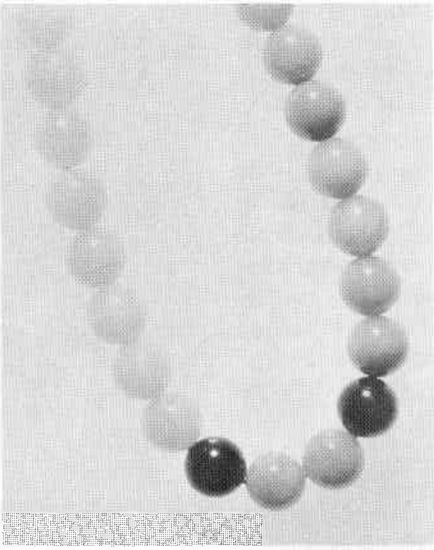

Figure 5

with weaker associated lines, especially one at approximately 5010Å *(Figure 3)*. Apparently undamaged discs did not show the lines. In *Figure 4* undamaged stones are on the left and the stone that appears to be most altered is in the center. All but the center stone sank in bromoform with a specific gravity of 2.85, indicating a possible mineral alteration.

Paraffin . . . its Pros and Cons

Multi-colored jadeite necklaces seem to be increasing in popularity. In most cases when we have tested such bead necklaces we have found all but the black beads to be natural-colored jadeite. In most cases, the black beads have been nephrite, so that the necklace is technically a jade necklace. The black beads in the necklace – shown in *Figure 5* – proved to be serpentine. However, the necklace was submitted because the client had noted wax or paraffin in the drill holes.

Figure 6

We have been informed that a final paraffin treatment is customary in the preparation of jewelry jades, particularly if any of the processes has included tumbling, as it might very well be in the case of round beads. The paraffin disguises unsightly fractures produced by the tumbling – fractures

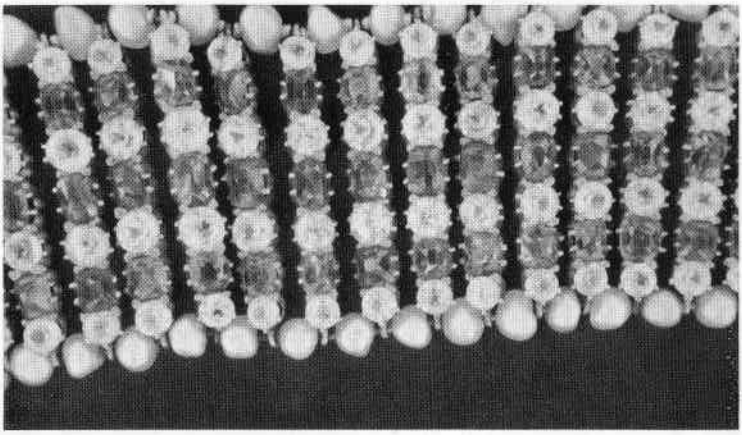

Figure 7

too shallow in most cases to affect durability. However, in the case of very thin flat cabochons or carved pieces the fractures may be serious and setters will break what should be a very tough stone *(Figure 6)*. This stone is one of several broken in setting and submitted to the Laboratory. It appears that the material contained more fracturing than usual but the fractures were disguised by paraffin with the result that setters did not exercise due caution. This is the same trouble we have reported with oiled emeralds.

A Spinel Oddity

Figure 7 is an unusual bib necklace containing hundreds of nearly identically-colored red spinels, pearls and natural-colorless sapphires. The spinels were unusual to us in that many seemed to be merely faceted octahedra or distorted octahedra *(shown in Figures 8 and 9)*. The effect was pleasing but the whole piece seemed oddly like costume jewelry.

Smoky Quartz

We received a selection of various stones from New York dealer, Allan Caplan. Among the stones were good examples of a smoky-brown quartz of the type that heat treats to a clear, attractive yellow. One dichroic color

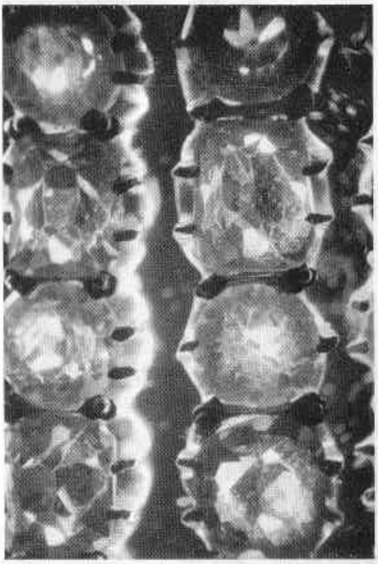

Figure 8

of the unheated stone is the yellow one sees in the heated stone. Other smoky quartz we have does not have the yellow dichroic direction and we assume would not "burn" to a good yellow color.

An Unusual Inclusion in Diamond

We recently encountered an almost complete octahedral inclusion in a round-diamond brilliant. The inclusion is slightly frosted which makes it possible to see the entire crystal. The tip of the inclusion was polished away when the table of the brilliant was polished; but as one would expect, since it is the soft direction, there is no evidence visible under ordinary magnification.

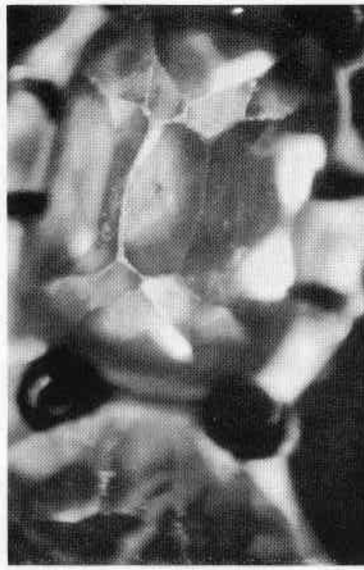

Figure 9

Developments and Highlights at GIA's Lab in Los Angeles

by

RICHARD T. LIDDICOAT, JR.

Turquois and Matrix

Leave it to GIA students to come up with the unusual – in this case, two unusual stones recently brought in for identification. One had been treated and one had not. They proved to be turquois in matrix and, in each case, the interesting feature proved to be the matrix.

In *Figure 1*, across the bottom of the cabochon, is a metallic mineral that appeared to be almost white in color but which proved to be pyrite. There are other metallic areas in the center and at the top right-hand corner of the cabochon. When the black areas were tested, they proved to be sphalerite. The turquois had not been treated.

Within a few days of the receipt of that specimen, we received another turquois cabochon which also had areas of black matrix. As in the first instance, the turquois itself had not been treated, but gaps in the material had been filled in with a black, nearly-transparent plastic material in

Figure 1

Figure 2

which there were spangles. Apparently the reflective objects were pyrite fragments, although these were not identified except visually. There were also some inclusions with metallic luster in the material. *Figure 2* shows the black areas from the top side of the cabochon, and *Figure 3* illustrates the spangled effect in the area of the lower side that had been filled with plastic material to improve the shape of the rather irregular cabochon.

Imitation of An Imitation

Among the items sent to us for testing, we encountered a dark-green stone that at first glance appeared to be a very dark, black opal with a green play of color. A more careful inspection suggested that it might be a goldstone with a lower-than-usual concentration of metallic crystals. Shown in *Figure 4*, at approximately 10 X magnification, it was easy to see that the highly-reflective metallic

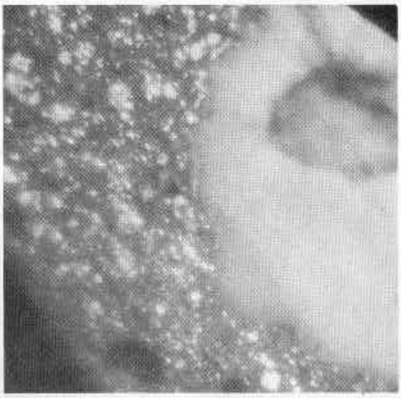

Figure 3

flakes were flat crystals or plates that appeared to be hematite. Apparently the maker had used specular iron ore as a source of the flakes that were dropped into the glass. This is an interesting looking imitation. Two individual grains are shown in *Figure 5* under about 25 X magnification.

Inclusions in Quartz

We examined a quartz that had been sent in for identification and noted many included crystals. They are shown under 10 X in *Figure 6*. The largest of the inclusions is shown

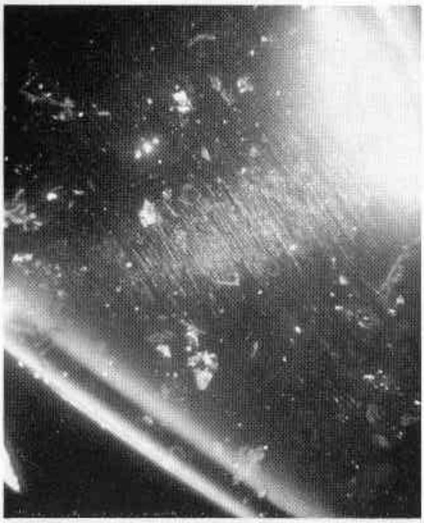

Figure 4

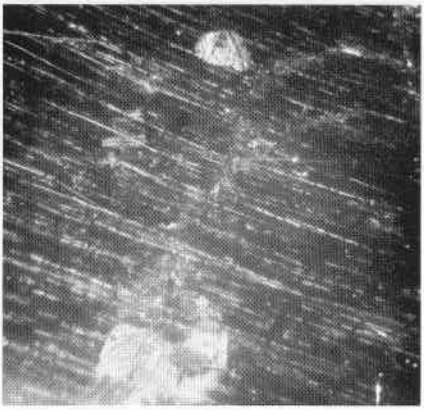

Figure 5

under higher magnification in *Figure 7.* The behavior of the combination in polarized light led Chuck Fryer to the conclusion that the main inclusions were calcite.

Black Opal

A rather attractive black opal was examined to determine whether it was of natural color, or had been treated. It was noted that some areas of the stone were unusually transparent. *Figure 8* was taken in transmitted light. It may be seen that all along one side of the cabochon the stone showed a high degree of transparency, and that there was one other area of transparency on the other side of a very dense central area.

A Classic Fingerprint

Anyone who has examined inclusions in natural gemstones has no

Figure 6

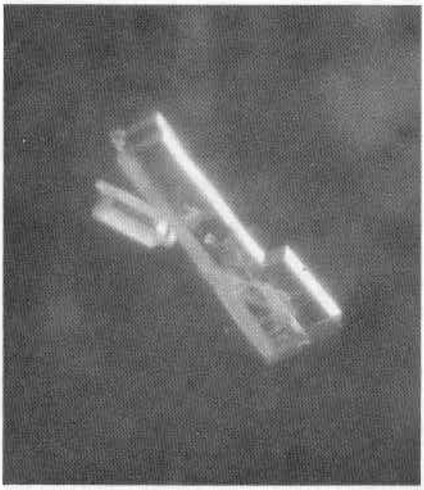

Figure 7

difficulty in appreciating why the term fingerprint was coined to describe the typical patterns seen in corundum and many other natural gemstones. Recently we encountered a pattern in a natural spinel that was so like the print of an index finger that we photographed it. It is shown in *Figure 9.* It is even more lifelike than the average, more angular fingerprint inclusion.

Asteriated Quartz

A quartz cabochon was brought in because of the rather interesting pattern of inclusions that were arranged in a form that created a six-rayed star. This was not the usual star, but six dark rays caused by a concentration of the inclusions. The elongated inclusions had a reddish color. The pattern is shown best in *Figure 10*, but it is also visible, and the inclusions are seen somewhat more clearly in *Figure 11* taken under slightly higher magnification. The concentration of the needles makes for a just slightly-darker line at the planes where the right-and left-handed twinned portions join.

Diamond Pyromania

Recently, we have examined a number of diamonds that have been affected to various degrees by overheating. The table surface of a slightly-burned diamond is shown in reflected light in *Figure 12.* It had not been attacked evenly. The photograph, taken of reflected light from the table, shows the irregular darker areas that represent surface pitting.

A diamond that was severly burned is shown in *Figure 13.* Its table surface is shown in *Figure 14* under higher magnification. It can be seen that the etch or burn pits tend to have a squarish outline – the expected result on a four-point diamond, i.e., one with its table parallel to a cube face.

Additional Comments on Laser Drilling of Diamonds

The usual impression is that laser drilling is used to reach a dark inclusion in a diamond only when the inclusion is so obvious that it gives the diamond a grade well into the imperfect range. This is not the case. Often, laser drilling is used to relieve rather small inclusions that reflect

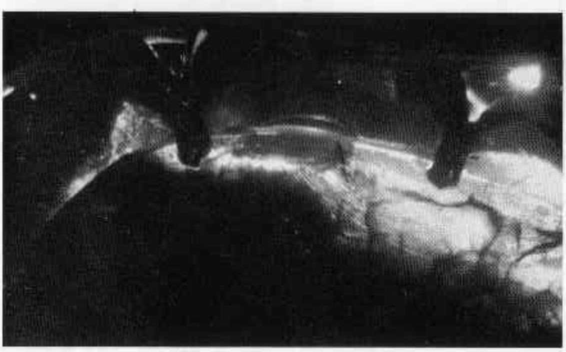

Figure 8

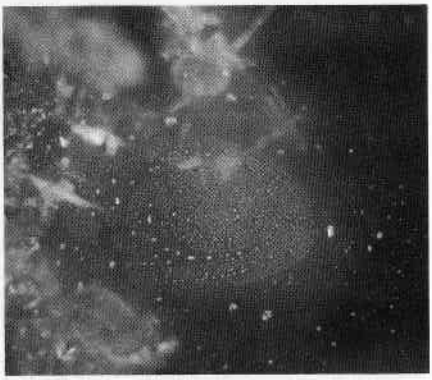

Figure 9

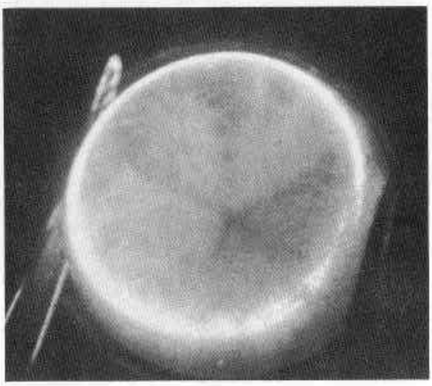

Figure 10

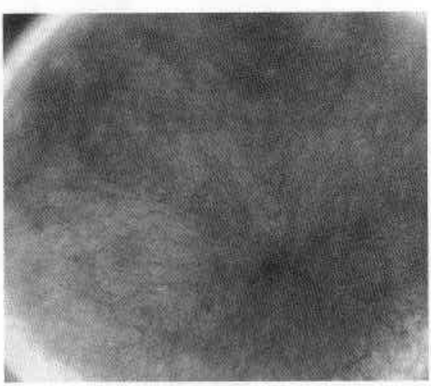

Figure 11

badly, or when the dealer believes that an inclusion is close enough to the surface that changing it from black to white would have a material effect on the clarity grade of the diamond. Such an instance is shown in *Figures 15 and 16* As viewed from above, the diamond shown in *Figure 15* would appear to have two small white lines going to an inclusion just barely inside the lower part of the bezel facet and seen again in the lower girdle facet. The inclusion is not really highly visible. The two white lines made by the laser drill holes are actually more visible than the inclusion, but before it was bleached, the inclusion may have been very obvious. These two drill holes enter from a lower girdle facet; they appear in *Figure 16* as two bright spots. The inclusion is to their left. It appears white in the photograph.

We were interested to learn recently that the Chambre Syndicale Nationale, representing the French jewelers, issued from Paris on October 25, 1972, the following statement: "The committee calls its members attention to the absolute obligation in which all the French professionals find themselves to outline on memoranda and invoices diamonds that have been laser treated."

The wording adopted by the Diamond International Commission of the International Confederation of Jewelry, Silversmiths, Diamonds, Precious Stones and Pearls, during the Zurich meeting of July 3, 1972, is as follows: "Diamonds which inclusions have been artificially modified." In other words, all French jewelers are on notice that any diamond with inclusions that have been drilled by laser to bleach out black inclusions must be announced to customers.

New Opal Source

Recently we received from a graduate in Arizona a cut stone and two rough pieces of opal from a new source in his state. This does not appear to be a major development, but it is a rather attractive, relatively-dark opal with abundant matrix. It would lend itself to tumbling and to relatively low-quality cabochon cutting. It is the first source of opal with play-of-color in the state of Arizona in our recollection. It is always possible when such a new source is discovered that better qualities will emerge than those first discovered.

Blue Jadelike Material

We were asked to identify a grayish-blue cabochon that was relatively attractive. On the basis of its

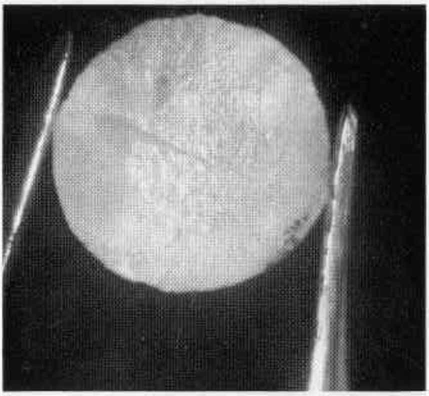

Figure 13

properties, it could be called nephrite (refractive indices on the order of 1.608 to 1.630, and a specific gravity near 3.00). However, it was very coarsely crystalline which is not a nephrite structure and it was actually dichroic. An X-ray powder diffraction analysis by Chuck Fryer showed it to be tremolite. Since nephrite is a term applied to a combination of tremolite

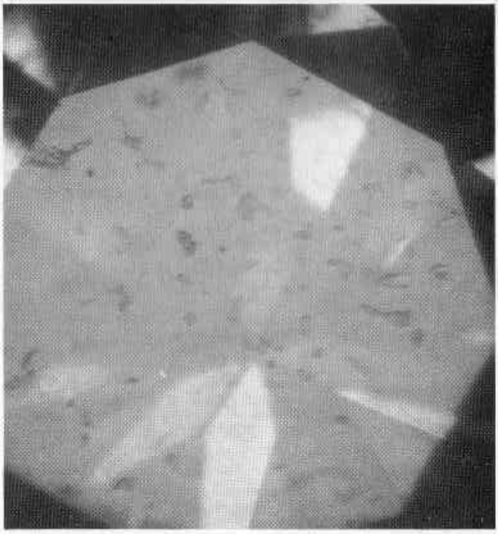

Figure 12

Figure 14

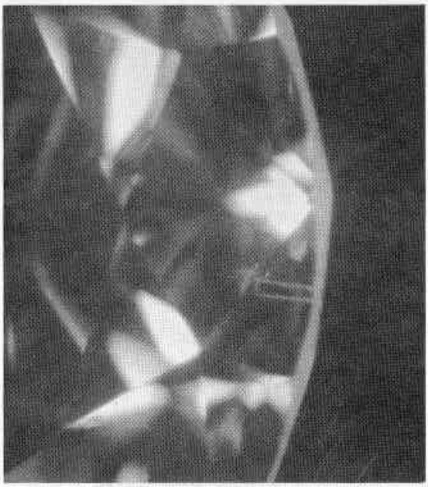

Figure 15

Figure 16

and actinolite in the amphibole group, for a very fine-grained matted structure, the person who had the material could not be faulted for calling it nephrite, even though we would not.

The most interesting feature of this material was the fact that it had a strong absorption line at approximately 4370Å the position for the characteristic jadeite line. This is the second time we have encountered a material with the refractive index and specific gravity of nephrite that showed a strong absorption line in the jadeite area.

An Unusual Blue Sapphire

We received for identification a handsome blue sapphire in a mounting

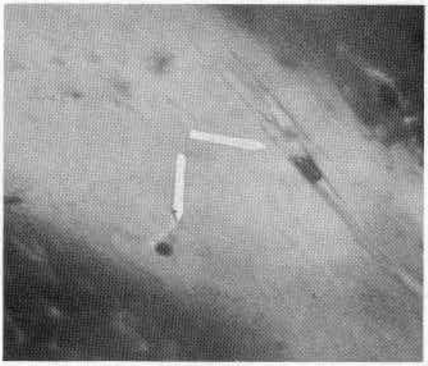

Figure 17

that restricted to some extent the opportunity to examine it from all directions. In one section it showed strong fluorescence to short-wave ultraviolet – a characteristic of synthetic blue sapphire – and it lacked the absorption line in the 4500Å area that is usual in natural blue sapphires. It was a very rare natural sapphire that showed no absorption. There are, however, some blue sapphires, especially those from Ceylon and occasionally from Kashmir, that show only the faintest and sometimes no 4500Å line. The iron in most natural sapphires dampens the fluorescence that is usually seen under short-wave ultraviolet in the synthetic. An examination of this stone when immersed showed that the crown portion was deeply colored and most of the pavilion was almost colorless. There was strong color banding in the crown area with straight color banding very evident and one section with parallel bands intersecting the main portion (which were relatively parallel to the table) at an angle of about 15 to 20°. If one were to use only spectroscopy and fluorescence, the stone would have been identified as synthetic, when actually it was an attractive natural sapphire.

Diamond-Shaped Crystals in Three-Phase Inclusions in Colombian Emerald

In *Figure 17* arrows point to two crystals in three-phase inclusions which have a diamond shape. In each case the gas bubbles appear dark in these illustrations.

Cats' Eye Jadeite

We had never encountered a material that could be described by any stretch of imagination as a cats'-eye jadeite until a yellowish cabochon was brought in for identification. A large section of one end of the stone had a slightly vague but apparent chatoyancy.

What might appear to be an eye – the streak of light running at an angle across the trend of the inclusions – is actually a reflection of the stone holder. The eye was actually at right angles to the upper left to lower right of the inclusions visible.

A Plane of Inclusions In a Natural Emerald

Pyrite inclusions are not at all unusual in colombian emeralds, but to find them as widely dispersed in a single plane was seen in Fig. 18 is rare. This was a very attractive, if somewhat pale, emerald in which we are able to photograph all of the rather large number of pyrite inclusions.

Insects in Amber

Certainly the presence of insects in amber specimens from the Baltic is not unusual. We identified recently a specimen of amber with many insects. One of the insects was enlarged for a photograph at 63X. Fig. 19

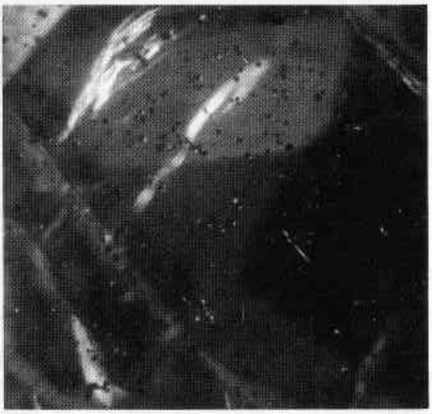

Figure 18

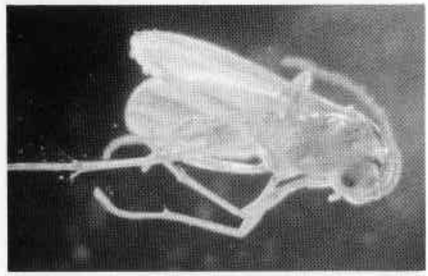

Figure 19

Thank You

We wish to express our sincere appreciation of the following gifts:

*DAVID KIRBY, David & Joseph Gem Co., Los Angeles, California, for an unusual glass jade imitation.

*ARCHIE CURTIS, recent Resident Graduate, Los Angeles, California, for a mixed assortment of cut stones.

*J. FRANK GOLDEN, Dallas, Texas, for the following rough specimens: peach beryl, golden and blue topaz, jadeite slab, quartz crystal group from Arkansas and an Hawaiian black coral.

*NAFTULE FILS, Geneva and Nafco Gems, Ltd., New York, for several attractive East African gems.

*SHERI HEMPHILL, recent Resident Graduate, La Porte's Jewelers, Pacific Grove, California, for a fine assortment of mounted colored stones.

*RUSSELL C. PATTIE, of Miller and Woodward, Lexington, Kentucky, for several gemstones that will be put to use for identification purposes.

*JOSEPH BEST, GIA student, California, for a fine selection of assorted stones.

*ED BORGATTA, Ph.D., G.G., for lapis lazuli cabochons

*JERRY CALL, former staff member, for a wide selection of citrines showing a wide range of color.

Book Reviews

* *AN ESSAY ABOUT THE ORIGINE AND VIRTUES OF GEMS by Robert Boyle. Facsimile of the 1672 Edition. Published by Hafner Publishing Company, New York, 1972. Clothbound. 185 pages. Price: Upon request from the publisher.*

(Editor's note: All quotes contained in the following review are given in modern English usage.)

"That the Scarcity, the Luster and the Preciousness of Gems have made them in all ages to be reckoned among the finest and choicest of Natures Productions, is generally granted. But whether the Books, that have been divulged of them, be answerable to the Nobleness of the Subject, seems not to me so unquestionable . . ."

Robert Boyle (1626 – 1691), British scientist and philosopher, who contributed to several areas of science, is considered by many to be the father of chemistry. His *Essay* on gems stands clearly as the first scientific contribution in the history of crystallography. In his *Essay*, Boyle recognizes "the mixture of metals and other mineral sources," which marks the beginning of the knowledge of crystal structure. He describes the formation of many crystals and explores the tendency of some gems and diamonds to cleave along crystal planes. He further adds a number of references to medical practices of the day.

This particular work is one volume of a reprint series on the *Contributions to the History of Geology*, and has been carefully edited by George W. White, Research Professor of Geology at the University of Illinois. It is indeed significant for, at the time of its publication it was far more than another book on the lore of gems. Today we realize that this highly sophisticated book, which appeared in 1672, opened a whole new world of experimental mineralogy.

The book is divided into two sections. The first section contains Boyle's five arguments supporting his theory on crystal growth. Essentially he notes that crystals form from solutions and concludes that transparent gems have similar origin and structure. His fourth argument, in particular, is most fascinating. It states that the color of some gems is accidental, due to a "colored fluid" or "mineral exhalation" and that this color is sometimes lost if the gem is heated. Today, of course, we employ these ideas, referring to allochromatic stones and the use of heat to improve the color of many gems.

Section II of the *ORIGINE AND VIRTURES OF GEMS* deals with seventeenth century mystical as well as medical practices involving pharmaceutical uses of gems. Here, Boyle's scientific skepticism is fully revealed – he dismisses the magical and conceeds to the medical. One such startling and noteworthy observation involves the toxic effects of mercury in combination with solutions over long periods of time.

Boyle then continues, touching on geological formations, effects of earthquakes, volcanic eruptions and shifting of land masses.

Robert Boyle's 300-year old *AN ESSAY ABOUT THE ORIGINE AND VIRTUES OF GEMS* is doubtlessly brilliant and without question, timeless. Reprints such as this afford the well needed bridging of past with present. *S.K.*

Editor's Note of Interest: Zeitlin & Ver Brugg Booksellers list a First Edition of Boyle's ESSAY at $1,400.00.

* *ANTIQUE JADE by Oscar Luzzatto-Bilitz. Published by The Hamlyn Publishing Group, Ltd., Middlesex, England. Available in the United States from Tudor Publishing Co., New York. Clothbound. 158 pages. 71 color plates. Price: $2.95.*

With some frequency, someone in some part of the world publishes a book on jade. The newest publication on this subject is the work of Oscar Luzzatto-Bilitz, entitled *ANTIQUE JADE*. It was translated from Italian by Francis Koval.

This attractive book is distinctive in that it contains 71 color plates. The author has created his story around his collection of carefully-chosen photographs. Accompanying each illustration is a brief paragraph or two, giving the reader some idea of what is involved; for example: "... Plate 52 – Bowl with lid. Ch'ien Lung period (1736-1795). Victoria and Albert Museum, London. Made of remarkably translucent greenish-white nephrite jade. Here the ornaments are sculptured and partly carved in filigree, thus achieving an exquisite effect on the vessel's lid."

Since the subject is antique jade, Luzzatto-Bilitz begins with a description of a Pi (a circular disc, with a hole in the center, said to be symbolic of the Heavens) which, in this instance, is believed to be at least 2,000 years old. From this point on, the author covers dynasty after dynasty, ending with the Ch'ien Lung era (1795).

Jade of pre-Columbian origin, as well as the jades of the New Zealand civilization, is also mentioned in the text.

Luzzatto-Bilitz cites the early history surrounding the travels of Marco Polo (14th century), and then, launches into a review of the ancient art of cutting, fashioning, and polishing jade. Centuries ago it was a laborious process. Today, of course, Chinese artisans use diamond saws, drills and powder, to expedite the handling of these hard, tough minerals.

The author of *ANTIQUE JADE*, obviously, spent many months in studying the famous jade collections housed in the great museums of Europe. He spent much time in comparing notes with the curators of these institutions, who are recognized authorities on jade.

Several of the museums visited are as follows: the British Museum, the Victoria and Albert Museum, the Museo Nacional de Antropologia (Mexico City), Museo Nazionale Orientale (Rome), Museo Poldi Pezzoli (Milan), the Metropolitan Museum of Art, and the American Museum of Natural History.

Luzzatto-Bilitz does not, unfortunately, include a bibliography (which would have been very helpful). In his text, he refers to Laufer, and comments on his years of research on jade. Since only an expert on the history of jade would know about Laufer, the layman is left to wonder who this investigator is – or was. (Berthold Laufer was – for many years – curator of archeology, Field Museum, Chicago.)

This little book is written for the layman – in language the layman can comprehend.

Even if you already own the works of S. Howard Hansford's *Chinese Carved Jades*, and Stanley C. Nott's *Chinese Jade*, you would do well to add *ANTIQUE JADE* to your book collection.

As one who has specialized in jade, I found the book engrossing. It carries my endorsement. *A.E. Alexander*