Gems & Gemology

GIA

FALL 1969

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gems & gemology

Volume XIII *Number 3*

FALL 1969

IN THIS ISSUE

ON THE NATURE OF MINERAL INCLUSIONS IN GEMSTONES

(Part II)

(Part I appeared in the Summer, 1969 issue)

by

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Plate E-1 to E-8: The general appearance of inclusions in almandite, kornerupine, sapphire, spinel from Oriental deposits, peridot from Zebirget and Burma, and in emerald from the mica-schist deposits (Habachtal, India, the Urals, Rhodesia and the Transvaal) is often characterized by varying numbers of inclusions of a mineral ranging in hue between yellowish and reddish brown or between grayish and dark brown and occurring as isolated, irregularly located scaly flakes, some of them twisted, or in the form of stacked slabs. It is only in peridot that they assume the shape of pseudohexagonal slabs; in other gemstones they are characterized by irregular contours or, at best, by a faint suggestion of imperfect crystalline forms. Their R.I.'s are in the region of that of emerald, and they display a very distinct pleochroism. In polarized light, very vivid interference colors are seen, whereas the extinction is usually indistinct.

Although optical tests suggested that these guest minerals were members of the mica family, determination of their chemical composition (i.e., the distinction between biotite and phlogopite, with their totally different geological environments) was found to be impossible. The mica family in the restricted sense comprises complex, mostly hydrous silicates of monoclinic pseudohexagonal and marked tabloid crystallization. When scanning these often rather slim inclusions bared on the surface of a number of gemstones, the microprobe indicated the presence of the following elements in almandite, kornerupine, and sapphire from Ceylon, peridot and emerald: Fe, Mg, K, Si and Al; and in the case of dark-blue sapphire of unknown origin and red spinel from Burma: Al, Mg, K and Si with minute admixtures of Fe and Ti. The constituting elements of biotite: $K(Mg,Fe)_3[(OH)_2(Al,Fe)Si_3O_{10}]$, were identified in the former case, and those of phlogopite, $KMg_3[(F,OH)_2AlSi_3O_{10}]$, in the latter.

Both of these micas crystallize in the monoclinic system and have a marked pseudohexagonal character. The basal pinacoid is the prevalent, often even the only recognizable, form of growth, and this is why the predominantly tabloid to flaky or fine-scaly form is a feature common to all micas. The biotite flakes may also assume an elongated bladelike shape. Except in peridot, the contours are mostly ill-defined or at least indistinct. For all its chemical variability, the optical properites of mica are fairly constant. The only two criteria subject to relatively wide variation are the size of the angle of the optic axes and the kind of absorption. But it is these very features, which often differ so enormously within one and the same mica group, in which optical methods fail to distinguish between its chemically different members.

Common biotites contain, apart from magnesium, not only divalent but also, for the most part, some trivalent Fe, which is responsible for the prevailing brown tints: n = 1.54-1.64, S.G. = 2.80-3.20, H = 2½ to 3.

Biotite, as the most common kind of mica, is a widespread constituent of most magmatic rocks, particularly of mica-schist, but is also a product of contact and depth metamorphism, as well of pneumatolytic and hydrothermal disintegration. It is therefore not surprising that it is encountered in many gemstones. It is found mainly, sometimes in large quantities, in such emeralds that have formed as a result of contact pneumatolytic processes in pegmatite veins of adjacent mica-schist (Habachtal, India, Rhodesia, the Urals and the Transvaal). The biotite enclosed in such emeralds is of preëxistent descent, in that it was transferred, as a relic of reabsorption, from the mica-schist into the emerald as it grew, and was thus encorporated by the latter. The biotite in Ceylon kornerupine and sapphire is probably to be considered a by-product of contact metamorphism, whereas in almandite and peridot it may be safely regarded as a product of depth metamorphism. Thus, it settled itself syngenetically in these gemstones.

In sapphire, biotite occasionally contains sparse admixtures of titanium, whereas in emerald it will display traces of chromium.

Phlogopite differs from biotite in that it contains hardly any iron, but it frequently contains fluorine. The fluorine may, however, be replaced in part by (OH). Where an abundance of Mg-silicate molecules is combined with Al-silicate, the tints are seldom intense, because Mg invariably has a bleaching effect. Although these phlogopites, which often contain more than 30% by weight of MgO, are rich in fluorine, the electron microprobe can only determine the absence of iron, but neither the presence of the F nor of the (OH) group. The physical properties of phlogopite differ from those of biotite as follows: n=1.534-1.566, S.G.=2.75-2.79, H=2½ to 3.

Phlogopite is a typical product of the pegmatitic pneumatolytic phase, but it also occurs as a constituent of granular chalks and dolomites of crystalline slate and its contact. Its occurrence in gemstones resulting from formation processes (e.g., the previously mentioned dark-blue sapphire and red spinel from Mogok, Burma) is therefore to be ascribed to syngenetic growth.

Plate E-9 to E-10: Apart from the ill-deliniated brown scales, the elongated blades and the stacks of biotite in emerald, and the small biotite tabloids in peridot with their clearly idiomorphous outlines, irregularly formed black granules of ore having a carbonaceous appearance are frequently present in the internal paragenesis of the two gemstones. In emerald, they occur singly and loosely dispersed or in dense clusters, even in large coarse lumps, whereas in peridot they are always found isolated and surrounded by a residual halo. Occasionally, minute or flat specimens may appear dark brown. Microprobe analysis identified the chemical elements Cr, Mg and Fe. The ore inclusions thus turned out to be chromite of the chemical formula $(Fe,Mg)Cr_2O_4$. It is sometimes slightly contaminated by other elements, such as Al, Mn, Ni, Ti and Zn. Chromite crystallizes holohedrically in the cubic system. It is not magnetite. n=2.10, S.G.=4.50-4.80, H=5½.

Chromium ore invariably depends on associations rich in olivine and on serpentines originating from them, wherein it occurs as a magmatic precipitate irregularly dispersed or aggregated in clusters. Another indication of its liquid-magmatic mode of formation is its occurrence in peridot, in which it was syngenetically produced. The author holds that the halos surrounding each individual granule of chromite are waste liquid drops or dried residues of liquid that were deposited on growth planes during the growth stages of the peridot, from which small crystals of chromite were subsequently precipitated in the course of a phase displacement. In emerald, however, a syngenetic formation of chromite (that is, after all, a product of magmatic formation) would appear to be unlikely, since the minerals are, we must remember, separated by a considerable period of genetic construction.

Plate F-1: An irregularly shaped mineral fragment of a pronounced light-green color happened to be exposed on the table of a brilliant-cut diamond, so that one part of the fragment was bared on the surface of the table. This tiny area offered an ideal object for investigation by electron microprobe, and the following elements were detected: Ca, Fe, K, Mg, Cr and Si (no Al). This combination of elements suggests pyroxene; i.e., augite. Pyroxene (augite), having a low alumina and alkaline content with $[SiO_4 \cdot SiO_2]CaMg$ as its main molecule, is called diopside. In very many cases, Mg is partly replaced by Fe. If chromium is also present, the mineral is called chrome-diopside. Diopside crystallizes in the monoclinic system. The crystals, which are often well developed, are columnar in shape and are not frequently found in aggregates of a granular or bladelike structure. n = 1.65-1.68, S.G. = 3.30, H = 6 to 7.

Emerald-green chrome-diopside evolves in olivine rocks and, as the main companion mineral to diamond, is also an important component of its inner paragenesis.

Plate F-2: Colorless prismatic or slab-shaped crystals often appear in dark-blue sapphires from Burma, Thailand and Australia, embedded either singly or in small groups without bearing any discernible relationship to the crystallonomic directions of their host. Their R.I. is clearly lower than that of the host sapphire, and a more or less oblique extinction can be seen in polarized light. The interference colors change according to the thickness of the small crystals. It is interesting to note that they are almost invariably found in the presence of a red mineral inclusion and black, ore-like grains, which will be mentioned later.

Electron microanalysis established the presence of the element groups K, Si and Al and Ca, Si and Al, thus proving these small bright crystals to be members of the feldspar family, more precisely orthoclase ($KAlSi_3O_8$), together with another feldspar of the plagioclase species, probably anorthite ($CaAl_2Si_2O_8$). Unfortunately, Na, with its atomic number 11, cannot be detected by the electron microprobe. Because of the considerable mixing ability of feldspars, no absolutely valid constants can be given for these inclusions, only mean values of their physical properties, as follows: n = 1.52-1.58, S.G. = 2.56-2.77, H = 6 to 6½.

All feldspars belong to the same morphological type, having little inherent variability. Monoclinic and triclinic feldspars reveal the same form of development. Feldspars constitute an extremely important group of rock-forming minerals that originated during various genetic cycles; e.g., the magmatic, the pegmatitic and the contact metamorphic. Their occurrence in sapphire might be an indication of the pegmatitic origin of this gemstone, a possibility that is reinforced by the other accompanying minerals of the inner paragenesis of these feldspar inclusions that were, we may take it, syngenetically formed.

Plate F-3 to F-4: Remarkable brownish-red topazes have turned up in the gem trade from time to time. Their bodies are interpenetrated with rust-red needles or hairlike fibers, either scattered sporadically or densely accumulated. On the one hand, the linear needles appear to be arranged irregularly, without regard to the crystallonomic directions of topaz; on the other hand, the crooked, twisted and folded fibers form tangled skeins. The more abundantly they occur, the more intense is the alien red hue and, of course, the optical turbidity of the host.

Apart from the pronounced red tint, crystalloptical analysis can give no positive indication, because of the sparse morphological clues and the hair-breadth shape of this kind of inclusion. The only possible means of investigation was the highly sensitive and subtle scanning process of electron analysis. It revealed the presence of one main element, Fe, besides traces of Ti and Ca. The results of this analysis, together with optical examination, suggest the presence of goethite ($\alpha FeOOH$). This indicates a new and interesting occurrence of goethite in gemstones, particularly since in topaz it is to be attributed to syngenetic-formation processes and not, as in other cases, to exsolution. Goethite crystallizes holohedrically in the orthorhombic system, and develops prismatic, short-columnar individuals ranging from needle shape to hair shape, which are elongated after the c-axis. They frequently assemble to form scaly, flaky or coarse aggregates, often displaying a texture of divergent fibers. The optical data is high: n = 2.21-2.35, S.G. = 3.80 to 4.30, and H = 5 to 5½.

Goethite is a characteristic product of the weathering zone and the area of vadose waters. Thus, like limonite, it shows an affinity for the oxidization zones of iron-ore deposits. It is also encountered as an independent mineral with calcite or quartz. Quartz, which occurs either in small, perfectly formed crystals or as tiny sandy grains in loose groups, can be observed in the same topazes paragenetically with goethite. Occasionally, these quartzes are found intergrown with chlorite, for which the electron beam revealed the elements Fe, Si and Al. The syngenetic formation of quartz in topaz is certainly compatible with the pegmatitic genesis of these two minerals, of which either may be the guest of the other.

Plate F-5 to F-6: Gemologists interested in inclusions are well aware of the fact that the small, black octahedra arranged in straight or curved lines are a diagnostic criteria of spinel. They were first mentioned and depicted by B. W. Anderson (1). For a long time, they have aroused the analytical curiosity of a number of scientists concerned with inclusions, and some years ago – because of their appearance and the limited possibilities of optical identification – the author claimed them to be magnetite.

These small octahedra, which are black with a metallic luster, are more or less idiomorphically developed but often strongly distorted. They seldom occur singly, but are usually arranged in large numbers in straight or crooked lines and, as such, traverse large areas of the interior of the host. Thanks to their fairly widespread occurrence in spinels, it was not particularly difficult to find several specimens in which these little black crystals were exposed on a polished facet. Electron bombardment of the grains thus bared on the surface disclosed the chemical elements to be Fe and Al, as well as slight traces of Si and Ca. The latter may be regarded as insignificant impurities. Thus, these small black octahedra are not magnetite (Fe,Fe_2O_4) but a related member of the spinel group, namely hercynite ($FeAl_2O_4$) – a very welcome discovery that somehow fits better into "the chemogenetic picture." Hercynite is otherwise known under the pseudonym of iron spinel. Its physical properties are exactly those of a high-ranking member of the spinel group: n = approximately 1.80, S.G. = 3.95, and H = 7½ to 8.

Hercynite is predominantly of liquid-magmatic origin and forms coarse crystals with an indication of octahedral development. It often occurs as an accompanying mineral in titano-magmatic deposits, and is also widespread as an exsolution product of magmetically formed titanomagnetite. Its occurrence may well be attributed to unmixing processes in spinel, as well. Lamellar hercynite has recently been identified by H.K. Schubnel (42) as being an exsolved by-product in magnetite, which is responsible for the four-rayed asterism in diopside.

Plate F-7: A blackish-red almandite

of unknown origin was so thickly interspersed with small black and splintery grains of ore with metallic luster that the host had almost completely lost its transparency and appeared unnaturally dark. Crystallooptical methods were unable to yield information as to the nature of these small orelike splinters of black, ferrous appearance, although many of them were flush with the surface of the almandite. Careful scanning of the surface by the electron beam revealed the presence of Ti and Fe, thus suggesting the titanic-iron ore ilmenite ($FeTiO_3$).

The titanium-bearing iron oxide crystallizes in the trigonal-rhombohedral system and is akin to hematite. It develops a partly tabular, partly rhombohedral habit. Its R.I. varies according to its Fe_2O_3 content and tends to be higher than n = 2.72, S.G. = 4½ to 5, and H = 5 to 6.

Ilmenite is predominantly a liquid-magmatically formed mineral of alkaline igneous rocks; this, in itself, explains its occurrence in the inner paragenesis of garnet, which originated under identical conditions. It originated syngenetically with its host and was enveloped by the latter as a secondary constituent of the same phase of formation. It is also possible that ilmenite is genetically older and was enveloped by garnet, but ilmenite is known to have formed in crevices of the St. Gotthard, so syngenetic formation can hardly be excluded.

Ilmenite in beryls was previously identified by W. F. Eppler, using optical methods (7), to be an inclusion resulting from exsolution. Moreover, ilmenite, as an exsolved mineral, accompanies other iron ores in gemstones (42); e.g., as lamellae in the magnetite needles in star diopside or in the pyrrhotite in ruby and sapphire.

Plate F-8 to F-10: Colorless, transparent crystals of euhedral habit of the rhombohedral system and their cleavages are known as innerparagenetic features of rubies and spinels from Mogok and emeralds from the Muzo Mine in Colombia, especially when they occur only sporadically and do not predominate in groups or extensive intergrowth. Many of these guest crystals are distinguished by twin lamellae parallel to $[01\bar{1}2]$, on whose lamellar planes weak interference colors appear when the gem is revolved. Under extreme magnification, two systems of alternately broad and slim lamellae can often be recognized. The R.I. is clearly lower than that of ruby and spinel, but corresponds roughly (with variation on either side) to that of emerald; D.R. is very pronounced.

There are two reasons for assuming that the enclosed mineral in question is calcite: the appearance and optical behavior of the material, and the specific occurrence of the host minerals in a source of rock of granular, marblelike limestone, in which they were formed by contact metamorphism. Since, however, scientific research cannot be content with mere assumptions, the microprobe was the only possible means for obtaining a conclusive answer. All of the exposed samples of the above-mentioned mineral inclusions revealed only Ca. Since C and O cannot be analyzed because of their low atomic numbers, calcite ($CaCO_3$) is the only possibility here. Calcite is a typical representative of the trigonal-scalenohedral class of crystals. Its habit and face development are strongly influenced by accompanying solvents. The number of its various forms of growth, and of their various combinations, is therefore very high. In Burma ruby and Muzo emerald, the rhombohedral growth and cleavage form would seem to predominate, and of the various possible twinnings the most frequent would seem to be polysynthetic lamellation after $[01\bar{1}2]$. $n = 1.48\text{-}1.65$, S.G. $= 2.71$, and $H = 3$.

As a free mineral, calcite is formed by liquid-magmatic processes under pressure in magma having a low SiO_2 content, as well as in the last stages of pneumatolytic genesis. Furthermore, sedimentary formations may also supply limestones. Under the influence of metamorphosis, the latter may be transformed to marble. Contact metamorphosis of this nature, which took place under the impact of magmatic melts, is the origin of ruby and spinel in Mogok and of emerald in Muzo, and also of the syngenetic precipitation of calcite inclusions in such gemstones.

Plate G-1 to G-2: The fact that calcite also occurs in spinel from Mogok may hardly surprise us, when we consider that the growth conditions are the same as for ruby. It came, however, as a surprise when the electron analysis disclosed that calcite does not always occur alone in spinel, but is frequently interspersed with dolomite ($CaMg[CO_3]$) and forms interesting intergrowths with the latter.

These "double crystals" appear to adopt xenomorphic habits that are either octahedral, hexahedral or even irregularly warped. Their distribution corresponds exactly with the modes of concentration of hercynite, being arranged singly, in groups or in lines. Their appearance frequently seems to suggest that they might be fillings in negative crystals, half of them consisting of striped (twinned) calcite and the other of dolomite. In polarized light they extinguish alternately (i.e., in different positions) and in bright light they reveal vivid interference colors, whereas the lamellar structure of calcite is conspicuous with strong contrast. The refractive index of both foreign crystals is markedly lower than that of spinel.

Allowing for the fact that the country rock that was involved in the contact metamorphosis from which the spinel originated consisted of dolomitic limestone, it is easy enough to understand the genetic preconditions leading to the development of these interesting double crystals. Alternatively, however, the dolomite might have come into being as a result of partial displacement and metasomatosis of the calcite.

Plate G-3: Apart from the two aforementioned granular inclusions of chromite in emerald, another guest ore having a leaden-gray hue and a high degree of metallic luster was observed. It is characterized by a tabular habit with indistinct edges, and its appearance distinguishes it unequivocally from all the other orelike, dark-colored foreign bodies found in emerald. The chemical elements Mo and S, having been revealed by means of the electron beam, this kind of inclusion could be identified as molybdenite (MoS_2). The high R.I., $n = 2.03\text{-}4.33$, is betrayed by the high metallic luster easily perceptible on the inclusion. S.G. = 4.75 and H = 1 to 1½.

Molybdenite is a mineral characteristic of the perimagmatic to contact-pneumatolic ranges also being present in pegmatite veins. Consequently, it boasts the same conditions of formation as emerald and, therefore, may well have crystallized syngenetically with its host.

Plate G-4: In dark-blue sapphires from Oriental occurrences – probably from Kyaukpyatthat near Mogok in Burma, Kanburi or Bang-Kha-Cha in Thailand – or from Anakie in Australia, pitchblack microlites of a metallic luster are occasionally revealed under the microscope. They are conspicuous because of their well-defined micro-tabular or columnar habit, and this will be more marked when the crystals occur singly or in small groups; as their numbers increase they rather tend to give an impression of isometric shapes. The quality of polish obtained when they are cut in the surface of a sapphire would indicate medium hardness. The crystalloptical method failed to yield a definite identification of the chemical nature of this kind of inclusion. Electron bombardment, however, revealed the presence of the elements Nb, Fe, Mn and some Ta (and, in one case, even traces of Ti), so that the mineral could finally be identified as niobite $(Fe,Mn)(Nb,Ta)_2O_6$.

Niobite, with its high content of Nb and low content of Ta, is an end member of the isomorphous series collectively referred to as columbite. The guest mineral, having a low content of Ta, crystallizes dimorphically; i.e., in the tetragonal and rhombic systems, involving a divergent form of development: members rich in Nb will prefer tabular or prismatic habits. The refractive index, 2.45, is much higher than that of sapphire, whereas its specific gravity, amounting to 5.30, will effect an increase of the density of the host when it is present in large amounts. H = 6.

Niobite is a widespread and typical companion of granite-pegmatites, and its accessory occurrence in sapphire indicates that this gemstone from the above-mentioned deposits emanated from granite-pegmatitic contact melts. We may safely assume that the formation and inclusions of niobite were syngenetic.

Plate G-5: Pyrite, the "jack-of-all-trades" of the mineral world, was identified early by crystalloptical methods. It is conspicuous not only by its unmistakable shade of brass yellow and its pronounced metallic luster, but also by its surface physiognomy and its growth forms that are, generally, typically paramorphic. The very fact that it will most frequently precipitate in a variety of formation cycles ensures that it is encountered in many kinds of rocks and, as an inclusion, in various kinds of gemstones.

A number of completely xenomorphous and pseudomorphous individuals (such as some partially distorted shapes counterfeiting yellowish-brown, tetragonally prismatic zircons with pyramidal heads), whose exposed surfaces exhibited a high reflecting power, were subjected to electron microscanning. Since pyrite is noted for its tendency to form fantastic aggregates, it did not come as a surprise when the examination revealed the presence of Fe and S, thus identifying the inclusions as pyrite (FeS_2).

Pyrite is remarkable for its extraordinary wealth of forms. The habit of its crystals is predominantly cubic, octahedral or pyritohedral, involving a score of combinations. The crystals are usually well defined. In addition, there is also a diversity of aggregate formations. S.G. = approximately 5, H = 6 to 6½.

Pyrite is known to be ubiquitous among all minerals and can be formed under almost any conditions. When occurring in such gems as fluorite, sapphire and emerald (from Chivor), which were likewise generated in completely different formation processes, pyrite must certainly have crystallized syngenetically with its host.

Plate G-6 to G-8: The many varieties of black-ore inclusions, ranging in appearance from carbon-dull to an adamantine-metallic luster, do not usually permit a definite identification by microscopic methods, although they sometimes display clearly recognizable morphological characteristics. Fortunately, they are mostly present in such large quantities that there are almost always a number of specimens caught on the surface of the host stone, which are ideal subjects for electron-microprobe investigation.

These ore specimens, ranging from black to dark red-brown in color, are seldom euhedrally developed, but are mostly of granular or completely rounded shape; they can be observed in ruby, sapphire and emerald. They are normally microscopic, but they may grow to such sizes that they are perceptible to the unaided eye. The microprobe disclosed the elements Fe and S, occasionally in conjunction with traces of Ni. The ore inclusions examined were thus corroborated as pyrrhotite (FeS). S.G. = 4.60, H = 4.

Pyrrhotite crystallizes in the hexagonal system. The rare crystals constitute hexagonal slabs with stumpy prisms, which are frequently characterized by extremely fine, lamellar structure. The low nickel content is present in inserted pentlandite lamellae that were precipitated as a result of exsolution during cooling. The principal home of pyrrhotite is usually the basic plutonic rocks in which it can accumulate in certain areas and form extensive deposits. It is, however, also present in pegmatitic-pneumatolytic phases and in hydrothermal crevices, and was thus liable to be precipitated together with the growing corundum and emeralds and to be included by them.

When the quantitative proportion is relatively high, the mineral in question is pentlandite $(Fe,Ni)_9S_8$, a paragenetic compound that has been shown to be present in ruby and emerald. This nickel ore crystallizes in the cubic system and its lattice is characterized by an extremely close spherical packing of the S atoms. The mineral, which is generally of a coarse texture, very rarely displays clear crystal faces. Unlike pyrrhotite, it is not magnetic, but possesses the same range of color from bronze to dark red-brown. Its hardness is 3 to 4 and its S.G., 4.60 to 5.00.

This nickel ore is native to all liquid-magmatic pyrrhotite deposits, and its coexistence with pyrrhotite in internal gemstone paragenesis may possibly be attributed to preëxistent origin. The former frequently embraces the latter in meshes or cells, and is then partly an exsolution product of nickel-bearing pyrrhotite.

Plate G-9 to G-10: Crystalloptical and radiographic methods have established beyond doubt (8, 18, 20, 21, 31 and 36) that olivine belongs to the family of minerals constituting inclusions in diamond, so that further corroboration would hardly appear to be necessary. Nevertheless, a small colorless crystal found to be cut flush with the table of a brilliant-cut diamond appeared to be such an ideal subject that the author could not resist examining it under the electron microprobe. The little guest crystal revealed a positively lower R.I. than the diamond. In polarized light it extinguished almost parallel with the c-axis. It also displayed vivid interference colors, and the hardness of its cut surface appeared to be rather low. The diagnosis, duly expected in view of these preliminary observations, was confirmed by the electron-beam analysis on account of the detection of Mg, Fe and Si; in other words, the crystal included was identified as olivine $(Mg,Fe)_2SiO_4$, which had grown epitaxially and oriented on the octahedron, as do all olivines in the process of simultaneous diamond growth.

Another small crystal of similar appearance and behavior was located in another brilliant-cut diamond, again having been exposed on the gem's table. It did not, however, live up to expectations, but instead revealed the elements Ca, Mg, Fe and Si, together with traces of Ti and Al, under electron bombardment and is, therefore, a diopside $(CaMg[Si_2O_6])$. This enrichment of the inner mineral association of the diamond is certainly in accordance with the current hypothesis that diamonds were formed as the by-product of a high-pressure, high-temperature transformation of olivine rock into so-called griquaite nodules among whose constituent minerals olivine and diopside are to be numbered. Consequently, diopside was also formed syngenetically with diamond. Whenever chromium was present simultaneously, emerald-green chrome-diopside could result from the inclusion of minute traces of the pigmenting transition element.

Plate H-1 to H-3: The typical aspect of twinned aggregates of the sagenitic texture of rutile needles precipitated as a result of exsolution in blue and red corundum from Burma and Ceylon have long been known and have also been confirmed beyond doubt by optical and chemical tests. When densely accumulated, they are responsible for the well-known and much-prized asterism in rubies and sapphires. Although, when viewed in transmitted light, the disassociated rutile needles appear as brown to black dashes, dark-field illumination will reveal them as bright lines intersecting according to three principal crystallonomic directions. Other morphological shapes are hardly likely to be familiar to a gemologist, since he is less well acquainted with the granular to columnar prismatic habit encountered in nature. On the other hand, he will presumably be well aware of the fact that rutile occurs in such different tints as golden yellow, reddish brown and yellowish brown, but he will be less familiar with its crimson, dark-brown and black varieties. Such individual specimens as rutile (TiO_2) in sapphire and coarse aggregates in kyanite – which have certainly not subsequently evolved as a result of exsolution but, rather, simultaneously with the formation of the host crystal from the mother melt – were detected by electron-ray scanning, showing Ti to be the main element, with Fe occurring as an occasional impurity. The crimson specimens consist of pure Ti, whereas the brown and black individual specimens obviously owe their dark shades to an admixture of Fe.

Morphologically, rutile belongs to the tetragonal system. Generally, it prefers elongated prismatic habits of stout columnar, as well as needlelike to hairlike, shapes, forming the quaintest knee twins and polysynthetic, or cyclic, multiples. Many of the exsolved twins are conspicuous by their lancelike appearance, whose laws of intergrowth have not yet been determined. n = 2.616-2.903, S.G. = 4.25, and H = 6.

Apart from the fact that rutile frequently occurs as a secondary product of titanium-bearing minerals, it is also widespread as a microscopic secondary constituent, assuming the shape of very subtle needles in sedimentary and metamorphic and partly also in igneous rocks. In areas of pronounced metamorphosis, and also in pneumatolytic veins and druses formed hydrothermally, it will occur as large and well-defined crystals. It is certainly this cycle of formation that is responsible for the syngenesis of substantial individuals, as well as aggregates of rutile in almandine, kyanite, corundum and quartz.

Plate H-4 and H-5: Burmese ruby frequently betrays its origin by the pronounced features of its endogenesis, which not only comprise whorly coloring and clustered concentrations of exsolved rutile needles, but also the presence of a diversity of associated minerals. Apart from the guest minerals, already discussed, pale- to deep-yellow individual specimens, having a habit reminiscent of the shape of an envelope, have also been encountered. Their broad relief is indicative of a high refractive index, which is considerably above that of the ruby. The high birefringence is expressed in the extinction and the vivid interference colors. In the deep-tinted specimens, the pleochroism is clearly perceptible. The conclusions derived from these observations were confirmed beyond doubt by a number of microlites exposed on the facets of some rubies, in that the electron analysis led to the detection of Ti, Ca, Si and Al; hence, the mineral included is sphene ($CaTi[SiO_5]$).

Sphene crystallizes in the monoclinic-prismatic system, with flat prismatic, tabular, columnar or wedge -shaped habits, and in yellow, green and brown shades. Its optical properties are quite outstanding: n = 1.90-2.05, birefringence = .105-.135, S.G. = 3.40 to 3.60, and H = 5 to 5½.

The mineral is a widespread accessory mineral in intermediate igneous rocks, primarily in metamorphic rocks. Its syngenetic precipitation, together with ruby, is completely congruent with the process of formation of its host, since in the contact-metamorphic melt the necessary constituting elements emanated from limestone-marble, as far as Ca is concerned, but from granite magma with regard to Si and Ti.

Plate H-6: At times, the internal paragenesis of dark-blue sapphires is very intriguing because of the presence of small red crystals that, by the intensity of their color, provide a vivid contrast and liven up the endogenetic picture. The microlite inclusions are encountered singly or loosely grouped and are of such positively idiomorphous shape that, in previous studies of mineral inclusions, the small, clearly isometric crystals were thought to be spinels or garnets. In some cases, they seem to be closely related to adjacent residual fluid drops, from which they may have been precipitated. It is interesting to note that the two feldspars previously described were invariably encountered in the company of such small red inclusions.

It came as a particular surprise when electron-beam analysis indicated a complex compound of the elements Nb, Ca, U, Ti, Fe and Ta, with small quantities of Th and Si, thus revealing that these pretty red individuals were a member of the pyrochlore group; in fact, the presence of U identified it more closely as the uranpyrochlore mineral, answering to the chemical formula $(Ca,Fe,U)(Nb,Ca,Ti)_2(O,OH,F)_7$ and called hatchettolite.

Uranpyrochlore crystallizes in the octahedral system, forming idiomorphous individual crystals. The mineral is predominantly native to granite pegmatite. It is worthwhile mentioning that in the course of this study, and thanks to the electron microprobe, we have come across three typical pegmatite minerals included in sapphire: feldspar, niobite and uranpyrochlore, which leads us to conclude that at least some sapphires are of pegmatitic origin.

Plate H-7 to H-10: The peculiar inclusion characteristics represented by spherical to ellipsoidal grains have been known for some time and have frequently been the subject of lively controversy. These characteristics constitute a locally typical criterion of the inner paragenesis of almandite, kornerupine, sapphire and ruby from Ceylon.

The small, round xenogenetic bodies, traditionally regarded as metamict zircons, may be recognized easily by their single or multifold haloes, which B.M. Schaub (44) identified as tension cracks. Isotropization (i.e., the structural disintegration of once-normal high-zircon inclusions into metamict low zircons) is always accompanied by an expansion of volume, causing fine circular or radiating fissures resulting from internal stress in the embracing gemstone. Under low-power magnification, they faintly resemble the squatty beetle inclusions in amber, and occasionally they will be distinct from their host crystal by virtue of a pale-yellow coloring and, invariably, because of their broad, dark relief.

Crystalloptical methods failed to provide better identification of these isotropic mineral inclusions; electron-beam microprobe analysis, however, successfully proved the presence of Zr and Si, and also, in the fissures emanating from the solid substance, of Fe, Ca and S. Although the mineral inclusion has thus been identified as zircon ($ZrSiO_4$), nothing has yet been established as to its structural condition; i.e., whether it is present in crystalline or amorphous form. However, it is interesting to find an indication of impurities in the fissures that are indicative of hematite (Fe_2O_3) and anhydrite ($CaSO_4$).

Parallel with the formation of small fissures, traces of the product of disintegration have obviously penetrated the stress cracks. This may also explain the brownish coloration of some of these tension haloes, in that they probably emanate from minute traces of iron that are almost invariably present in disintegrating mineral inclusions. Bearing in mind that green metamict zircons have been found rather widespread in Ceylon, it is not really surprising that they should share among the mineral association included in a good many Ceylonese gemstones. Indeed, zircon in all its structural conditions (i.e., in the form of low as well as medium and high zircon) is one of the principal constituents by volume of the island's gemstone deposits.

By virtue of their lower readings, the physical data of the metamict zircons are distinct from those of normal zircons: n = approximately 1.80, S.G. = approximately 4.00, and H = approximately 7.

Apart from its metamict form, zircon is also present as crystalline specimens with well-defined crystal shapes and has, as such, been identified by electron microprobe in almandine, kornerupine and sapphire. Individual specimens are the most frequent, although small crystal groups and irregular intergrowths have also been encountered from time to time. Zircon is also found in large numbers as a microscopic secondary constituent in certain syenetic igneous rocks (magmatites). As an accessory, it is rather widespread; hence, it is also found in crystalline schists and clastic sedimentary rocks. As a mineral of primary precipitation it occurs as a preëxistent mineral inclusion, but owing to separation from metamorphic-formation processes, it is also encountered as a syngenetic internal companion of its host gems.

Because the mineral inclusions identified by electron-beam microprobe have been discussed individually, readers might be misled into thinking that they had been included in each particular host gemstone in isolation; i.e., without the presence of other minerals. This is not the case; in fact, they often constitute the inner paragenesis in conjunction with one another and occasionally in conjunction with other minerals, some of which were identified at an earlier stage, whereas others still remain to be identified. In the gemstones examined, they were encountered in the following groupings:

Almandite:	Apatite, biotite
	Apatite, pyrite
	Ilmenite, quartz, zircon
	Rutile, which was found in several almandites in the form of needles, was not considered worthy of further analysis
Aquamarine:	Quartz with epidote and apatite
	Biotite alone
Diamond:	Chrome-diopside, diamond, garnet, olivine

Disthene:	Potassium feldspar and rutile or anatase
Kornerupine:	Apatite, biotite (chalcopyrite?), (garnet?), zircon
Peridot:	Chromite alone
Ruby:	Apatite, calcite, rutile, spinel, sphene, rutile, pyrrhotite, sphene
Sapphire:	Biotite (phlogopite), rutile, pyrite, zircon (the mica is often of the titanium-bearing variety)
	Pyrrhotite and rutile
	Niobite alone
	Feldspar (plagioclase and potassium feldspar), niobite, uranpyrochlore (Hatchettite)
	Rutile alone
	Zircon with hematite and anhydrite
Emerald:	Biotite, chromite
	Biotite, pyrrhotite and pentlandite
	(Note: The biotite is usually of the chrome-bearing variety)
	Calcite
	Molybdenite
	Pyrite
Spinel:	Apatite
	Calcite alone or intergrown with dolomite
	Dolomite intergrown with calcite, hercynite
	Hercynite alone
	Phlogopite
Topaz:	Goethite and quartz, the latter occasionally with chlorite

It goes without saying that all the aforementioned mineral inclusions will also constitute an inner hermit-paragenesis on their own; i.e., without the presence of companion minerals.

The author's sincere thanks are due to Professor M. Weibel of the Institute of Crystallography & Petrography at the Federal College of Advanced Technology, Zurich, who, by his helpful suggestions, unfailing interest and valuable support, made the electron-beam analysis possible, and also wrote the reports of the experimental findings.

Thanks are also due to Mr. R. Gubser for kindly agreeing to prepare the samples and carry out the painstaking examination of them, a delicate and time-consuming task to which he devoted a considerable amount of spare time.

The author is also most grateful to Professor F. Laves for his permission to use the instruments and for generously placing colleagues at the author's disposal for this purpose.

The author is also indebted to Professor O. Mellis, and particularly to Professor K. Chudoba, for their thorough and critical examination of the present study and for their valuable suggestions for its improvement.

The findings published in this article constitute a first report on the initial stages of a steadily growing trend towards a comprehensive investigation of mineral inclusions in gemstones. The author is fully aware that certain of his conclusions regarding genetic inclusions are in need of more precise scrutiny and corroboration. Nevertheless, he hopes that this preliminary report might inspire some scientists interested in mineral inclusions to persevere in their research into the identity of those that have not yet been identified, so that our incomplete knowledge of their locally typical associations may be completed, along with our knowledge of their genetic processes.

Color Plate E:

1. Tabular biotite parcels in almandite.
2. Brown biotite platelets in kornerupine from Ceylon.
3. Pseudohexagonal and spotted biotite platelets in peridot.
4. Dense concentration of biotite in pink sapphire from Ceylon.
5. Dark-green flakes of biotite in emerald from the Transvaal.
6. Irregular concentration of biotite flakes from the Habachtal.
7. Red-brown phlogopite in sapphire (Ceylon?).
8. Tabular phlogopite parcel with broken borders in spinel.
9. Microlites of chromite in the center of a residual fluid drop in peridot.
10. Irregular aggregates of chromite in emerald.

Color Plate F:

1. Green fragment of chrome-diopside in diamond.
2. Feldspar crystals in sapphire.
3. Hair-fine, fox-red fibers of goethite and individual quartz crystals (bright patches) in topaz.
4. Dense cluster of quartz grains surrounded by hairlike fibers of goethite in topaz.
5. Tiny octahedra of hercynite arranged in parallel lines in spinel.
6. Concentration of hercynite octahedra arranged in parallel array in blue spinel.
7. Dense concentration of ilmenite in almandite.
8. Idiomorphous calcite crystal displaying a rhombic pattern of lines caused by intertwined twin lamellae in Burma ruby.
9. Euhedral crystals, partly well preserved and partly as cleavage fragments, enclosed in emerald from the Muzo Mine, Colombia.
10. Xenomorphous, pseudoöctagonal calcite in red spinel from Burma.

Color Plate G:

1. Xenomorphous intergrowths of dolomite and calcite, partly filling octahedral cavities in blue spinel.
2. Enlarged area of Photograph G-1 exhibits the difference between dolomite and calcite in one of the filled cavities.
3. Two tabular fragments of molybdenite in emerald.
4. Well-developed microlites of niobite in sapphire.
5. In the center of the photograph there is a slightly damaged pyrite accompanied by flakes of biotite (brown) and fine silk of rutile needles in sapphire from Ceylon.
6. Pyrrhotite of ideal development in ruby. Diagonal lamellae of some exsolved minority component are distinctly seen.
7. Resorbed pyrrhotite grain in sapphire.
8. Grains of pyrrhotite and pentlandite of varying sizes and irregularly dispersed through an emerald.
9. A crystal of olivine flush with the table facet of a brilliant-cut diamond.
10. A fragment of chrome-diopside exposed on the surface of the table facet of a brilliant-cut diamond.

Color Plate H:

1. Irregular conglomerations of a black and red mineral, whose chemical composition of TiO_2 indicates either anatase or rutile, in kyanite.
2. Huge prisms of red rutile in sapphire from Ceylon.
3. Black rutile resorbed into a ball-like shape and surrounded by a stress halo in sapphire from Montana.
4. Well-developed crystal of sphene in ruby from Burma.
5. Group of pale-yellow sphene crystals in ruby from Burma.
6. Brilliant-red, euhedral crystals of uranpyrochlore (hatchettite) in sapphire (the bright spots are feldspars).
7. Rounded grains of metamict zircon surrounded by tension cracks in kornerupine from Ceylon.

E


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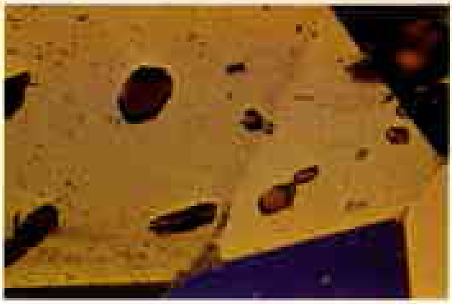
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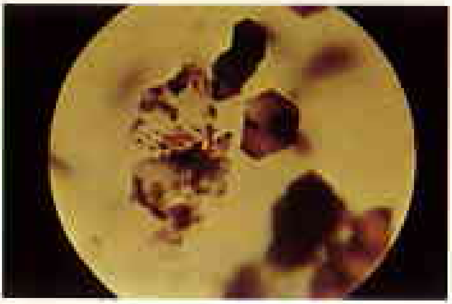
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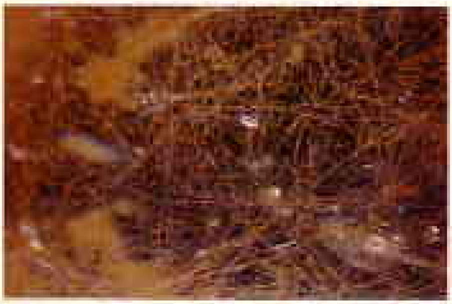
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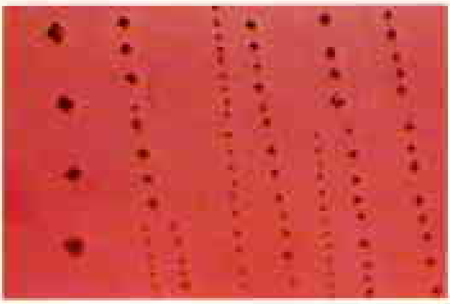
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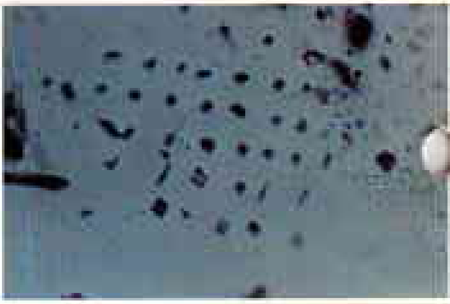
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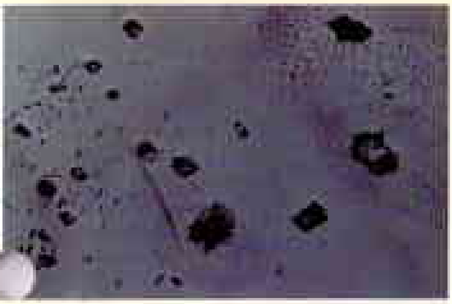
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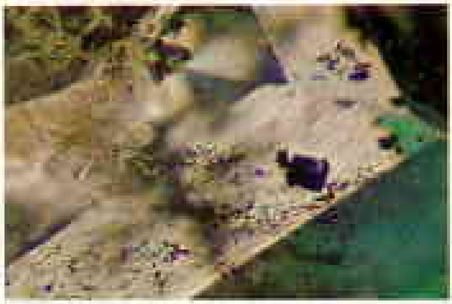
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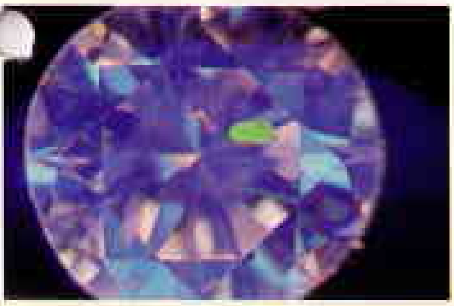
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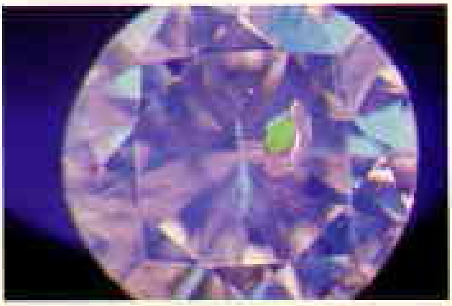
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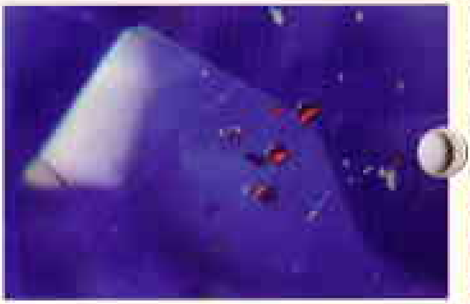
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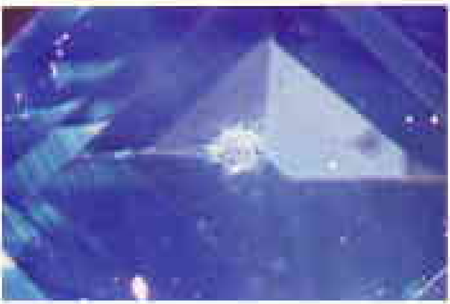
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Developments and Highlights at GIA's Lab in New York

by

ROBERT CROWNINGSHIELD

Unexpected Absorption Pattern

We have examined the absorption of colored diamonds for so many years we were beginning to think that nothing new would be seen. However, a 4-carat gray, round brilliant gave the unexpected absorption pattern seen in *Figure 1*. The stone was exceedingly fluorescent (*Figure 1A*) under both long- and short-wave ultraviolet. Amazingly, the fluorescent color was blue with a zone of yellow. The photograph was taken with only the fluorescence as a light source.

Rare, Transparent Actinolite

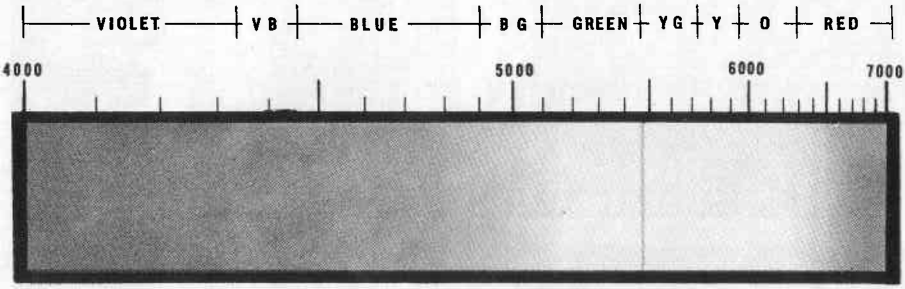
A rare collector's item examined in the Laboratory proved to be a dull-green, transparent actinolite weighing 1.06 carats. With its color and a refractometer reading similar to that of tourmaline, it was helpful to be able to obtain an interference figure. The absorption spectrum is shown in *Figure 2.*

Largest 3-Phase Inclusion

We were grateful to GIA student Yasukazu Suwa, Tokyo, Japan, for a 1.17-carat emerald with excellent 3-phase inclusions, ideal for student study. Among the 3-phase inclusions present was the largest we had ever seen. The gas phase is clearly visible in *Figure 3*. The stone illustrates another factor useful in teaching: many of the open fissures were filled with an oily-green substance.

Orange-Brown Treated Diamond

One color we used to see in treated diamonds that we seldom see today is a very attractive orange-brown. They were produced by cyclotron treatment and, we are told, not available from atomic-pile treatment. Some of the best were top-treated. When placed in a closed bezel setting, such as a man's gypsy ring, the color zone may be invisible, and, since the color penetration is only "skin deep," the expected



4.28 ct. dark bluish gray diamond

Figure 1

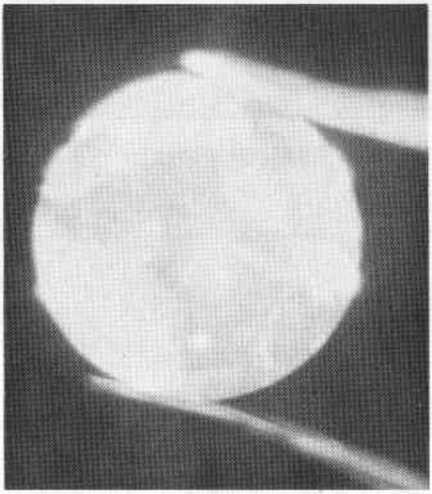


Figure 1A

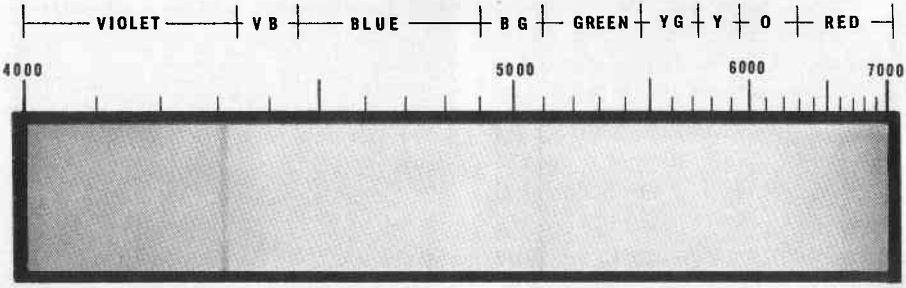
absorption spectrum may not be seen. One such stone examined recently after removal from the setting showed a thin band of color outlining all the star facets and the table (*Figure 4*).

By coincidence, another culet-treated stone of the same color was examined the same day. Neither stone had the typical treated-diamond absorption spectrum.

Modern Rose Cut

We examined a modern piece of gold jewelry with dark-purplish rubies and some peculiar rose-cut diamonds. We were informed that they were modern "bruted" roses. *Figure 5*

Figure 2



1.06 ct. transp. green actinolite (NY 44707)

Figure 3

Figure 4

Figure 5

shows the very thick girdle of such a rose-cut stone, indicating that it was not made from a cleavage piece, as original stones were.

Smoke-Treated Opal?

Figure 6 shows the surface of what was a very attractive, high, opal cabochon. It did not have the typical appearance of a treated opal, yet in some cracks, and especially in polishing cracks, we could see a concentration of dark brown to black. We received permission to polish a small area on the girdle, which revealed the superficial nature of the coloration. We assumed that it was an example of the rarely encountered smoke-treated opal.

Tissue-Graft Pearls

Accidental tissue-graft salt-water cultured pearls are not common. *Fig-*

Figure 6

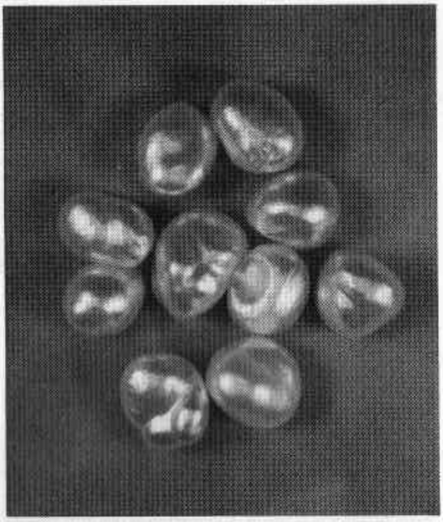


Figure 7

ure 7 shows ten cultured baroque pearls, nine of which are tissue graft and the tenth, a normal nucleated cultured pearl. It seems that these occur when the mother-of-pearl nucleus is eliminated by the host animal, but the tissue remains to form the nucleus of the resultant pearl.

Flawless Sapphires

Figure 8 shows a diamond-and-sapphire bracelet, not unusual for design, but for the fact that all 40 sapphires were without flaws under 10x magnification. The color and relatively strong absorption spectrum indicates that they were of Montana origin. The surface wear and design of the setting indicates that the piece was at least 60 years old. For precision of color matching and freedom from flaws, this collection of sapphires was unique.

Color Banding in Treated Diamond

Unusual cloudy texture and color banding in a treated yellow-brown diamond is shown in *Figure 9.*

Flux-Grown Synthetic Rubies

We have encountered several flux-grown synthetic rubies lately. One of them had some triangular metallic inclusions, probably of the platinum group of metals (*Figure 10*). The color of the stone, and of most we have seen in the Laboratory, was a dark purplish red of the tone one associates with the so-called Siam grade. However, unlike the Siam type of natural stone, these fluoresced very strongly under long-wave ultraviolet and enough stronger under short-wave ultraviolet, when compared with natural stones, as to be identifiable.

Chrome-Green Grossularite

We received a fine chrome-green grossularite as a gift from Mr. Arnold Schiffman, Greensboro, N.C. Under magnification this stone had a plane of breadcrumb-like inclusions and several

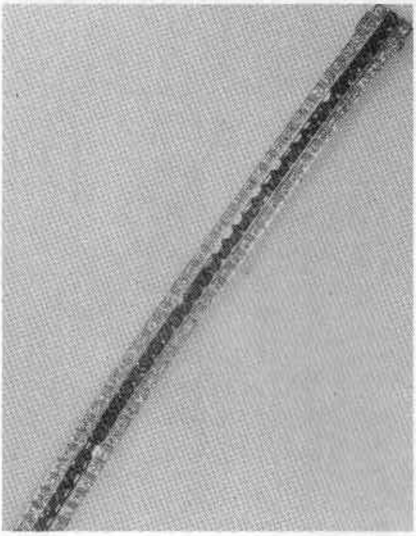
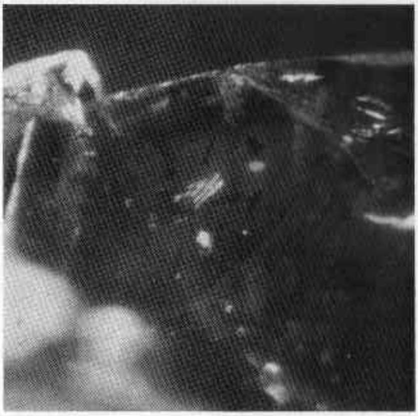


Figure 8

Figure 9

hollow tubes resembling fulgurites. The short one seen in *Figure 11* (arrow) reminds one of a sugar-encrusted quill. The two black ends were caused by foreign material, probably from the polishing wheel, which had entered the tube at the point where it reached the surface.

Figure 10



Calcite Inclusions in Emerald

The calcite inclusions shown in *Figure 12* resemble a flight of birds or the design of some modern jewelry. The inclusion was in a fine 12-carat emerald presented for identification.

Unusual Nucleus

Figure 13 shows the white core of a large, natural-color black pearl. The peculiar structure of the core, shown in *Figure 14*, was coarse and lacked orient.

Yag Now Has Name

Under the trademarked name *Diamonaire*, the Airtron Division of Litton Industries put the first colorless synthetic-garnet-structured yttrium-aluminum-oxide stones on sale in October. They met with instant acceptance as a truly colorless, hard, singly-refractive diamond substitute. Some of the properties were discussed briefly in the Spring, 1969, issue of *Gems &*

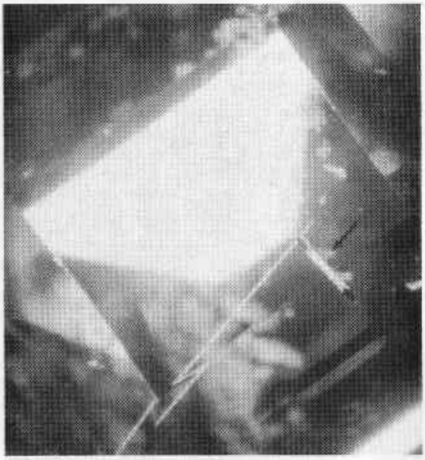


Figure 11

Figure 12

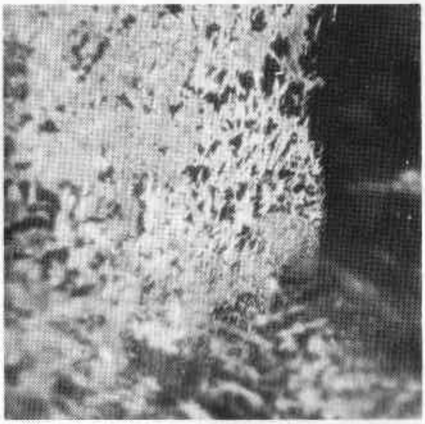
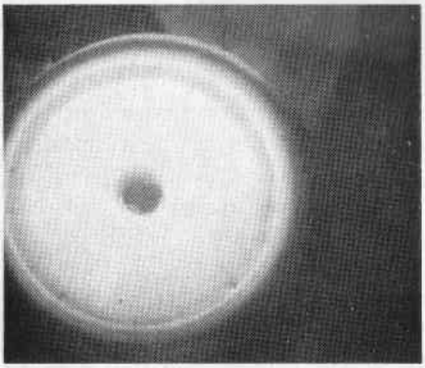


Figure 13



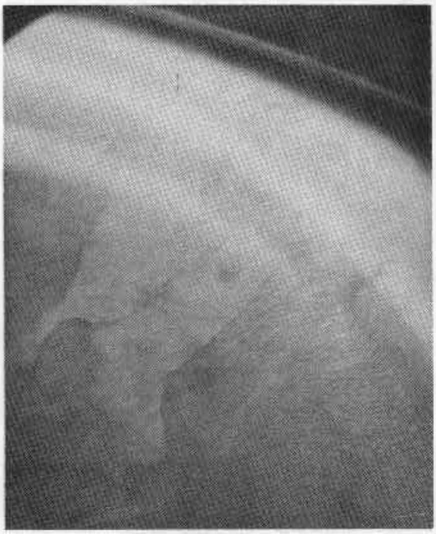


Figure 14

Gemology. The stones were called by the name given them by the original researchers: yttrium-aluminum garnet (YAG, for short).

GIA's New York staffer, Jerry Call, G.G., as lapidary consultant for Airtron, worked out the proper angles and proportions for the new material, so that when viewed face up they are excellent diamond substitutes (*Figure 15*). However, the refractive index is not high enough to prevent light leakage as one views the stones at an angle through the table (*Figure 16*). The larger stone is *Diamonaire.*

As with most colored stones, the facets may not meet as precisely as in diamond and there may be more pronounced polishing scratches. *Figure 17* shows both of these features.

Some stones we have seen cut for maximum yield from the boule may have naturals on the girdle (*Figure 18*).

One stone, a 9-carat emerald cut, had some unusual swirls around some

Figure 15

Figure 18

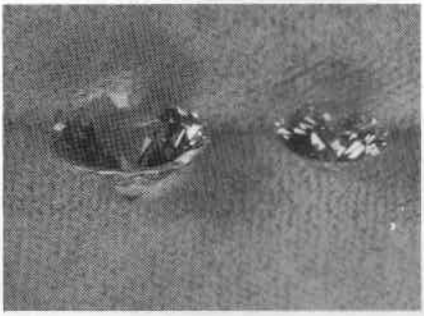


Figure 16

Figure 19

Figure 17

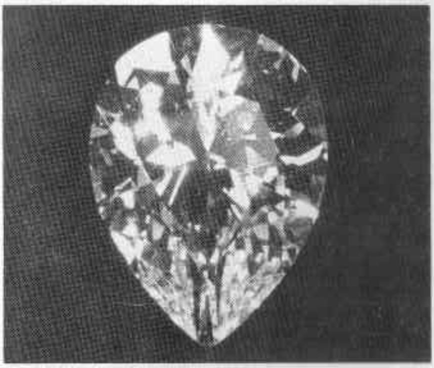


Figure 20

of the gas bubbles that were present (*Figure 19*).

Most stones examined were completely free of inclusions or had exceedingly minute gas bubbles not visible under 10x.

Cartier, Inc., chose this material over other colorless stones available out of which Jerry cut a replica of the 69.42-carat diamond soon to be delivered to Richard Burton for Elizabeth Taylor Burton. *Figure 20* illustrates the replica, which weighed 87.20 carats.

Acknowledgments

We wish to express our sincere thanks for the following gifts:

To New York gem dealer **Aldo del Noce** for a fine selection of red-spinel crystals, opal doublets and jade, all of which we will find good use for in student study sets.

To **Mr. Keller** of Kelsol Diamonds, Inc., for a gift of several pink and blue single-cut diamonds.

To **Don Thompson**, from De Beers Consolidated Mines, Ltd., for four beautifully formed pale-green diamond crystals from the new Finsch Mine in South Africa.

To **George Schuetz** of Larter & Sons, Newark, New Jersey, for a matched pair of jadelike hydrogrossular tablets.

To **Ira Serrit**, a friend of the Laboratory, for a crystal of ruby in matrix from Afghanistan.

To **Melvin Strump**, Graduate Gemologist and stone dealer, Superior Gem Co., for a necklace of emerald-green fluorite beads.

Also, through Strump's good offices we received from, and wish to thank, **Mr. Baden** of Baden & Foss for a wide selection of stones–natural, synthetic and imitation–that will find good use in student study sets.

To **New England Lapidary** for an excellent example of the very early type of synthetic ruby that, until a few years ago, was called "reconstructed."

Developments and Highlights at GIA's Lab in Los Angeles

by

RICHARD T. LIDDICOAT

Unusual Opals

Laboratory work in the gem field continues to be endlessly fascinating. Occasionally, one will encounter a variety of a gemstone that will not be seen again for many years—in fact, for so many years that one doubts the credibility of the earlier-reported property figures.

At least 20 years ago, we received in the Los Angeles Laboratory a red fire opal that had a refractive index near 1.38. For a long time thereafter no other such opal was encountered, although some in the vicinity of 1.40 were seen. Very recently, we encountered a black opal, a very lovely stone, that gave a reading of approximately 1.37.

A parallel story on this subject is the fact that our well-known Joe Murphy, chief Diamond Course instructor, has worked for many years on the refinement of estimations of weight by measurements. Using his highly accurate methods for the estimation of the weight of a cabochon, this stone, had it had a normal opal specific gravity, should have weighed about 8 carats. It actually weighed 5.97 carats. When we took a hydrostatic specific gravity, the figure was approximately 1.42.

Within the next few days we received a white opal that also had a refractive index of about 1.37. In this case, when we tried specific gravity, we found that the result was almost impossible to obtain, because the stone absorbed water so rapidly that its weight in water kept increasing as we were trying to make the test. When we first started, the weight in air was approximately 4.2 carats, but by the time we had finished it had risen to over 5.00.

The man who brought the material told us he had bought it at a local gem shop, to which we sent one of our instructors. He had some difficulty in obtaining specimens, but he saw material that was milky at the center and with a great play of color, but it was almost colorless and transparent in a coating at the surface. We were suspicious, thinking that this could have been some kind of synthetic opal, but we remembered that there is a source in Mexico that produces natural opal of this description. Under magnification, the opal material showed a definite structure to its play of color. It appeared as if there were large grains in which play of color was uniform, and there were areas with no play whatever. This granular structure is shown rather well in *Figure 1*.

We are actively seeking to gather further information on this material, because of its exceedingly low refractive index, specific gravity and marked hygroscopic properties. It is not exactly like any natural opal we have encountered, and, in the absence of any reported marketable synthetic opal, we feel that this is something that should be watched closely.

Hornbill Ivory

The Laboratories studiously avoid involvement in identifications that are out of its field in any respect. However, they are very frequently called upon to identify the nature of the materials in snuff bottles, some of which are not really gemstuff. Occasionally, materials used in snuff bottles are rather exotic by gemological standards.

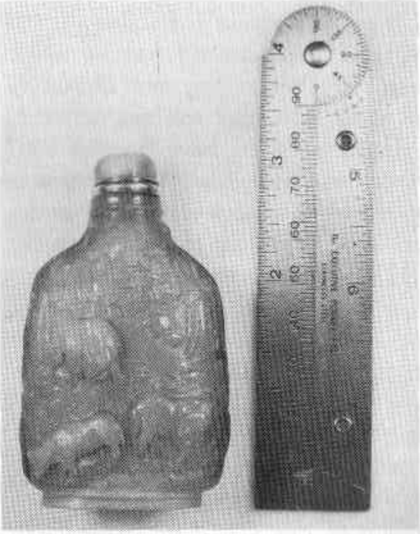
One of the most unusual, and to the snuff bottle collector exceedingly valuable, is the substance called hornbill (*Figure 2*). This is cut from the beak of the hornbill bird, particularly the helmeted hornbill, which is found only in Indonesia. It is approaching extinction.

The bird is about five feet from beak to tail and has a large head. The beak material is yellow, and the helmet covering the top of the head is brownish red.

When we were sent a snuff bottle purported to be hornbill ivory, we examined it to study its structure and

Figure 1

Figure 2



to measure its properties. We attempted to look up as much information as possible about the properties of hornbill, but we found the information very scanty. We were able to obtain from the supplier a number of other known hornbill objects (*Figure 3*), and those we tested had a specific gravity of about 1.28 and a refractive index of approximately 1.56. This substance showed no reaction to hydrochloric acid and had a greenish-white to bluish-white fluorescence that was rather stronger under long-wave than short-wave ultraviolet. To a hot point they gave an expectable burnt-hair odor.

The unknown that we examined was slightly more translucent than the known hornbill materials, and had a specific gravity of 1.36, compared with 1.28 for the known hornbills. It showed none of the lamellar structure that we encountered in the other specimens.

We were able to prove to our satisfaction that some of the carvings on the flat surfaces and the red of the helmet on the edges had been applied artificially. This had been known to the dealer, so it came as no surprise to him; but he had been convinced, with good reason, that the main material was indeed hornbill. This was far enough out of our field that we did not feel qualified to say whether the base was or was not hornbill. All we could do was to point out that the properties of the material did not agree with those of the known hornbill materials that we had studied.

"Petrified Mushroom"

Recently, we received a section of gray agate from a gemologist who, upon examining the piece, concluded that some sort of fungicidal growth form, such as a mushroom, had been replaced by chalcedony during the growth process. In other words, instead of petrified wood, he concluded that this was probably a "petrified mushroom."

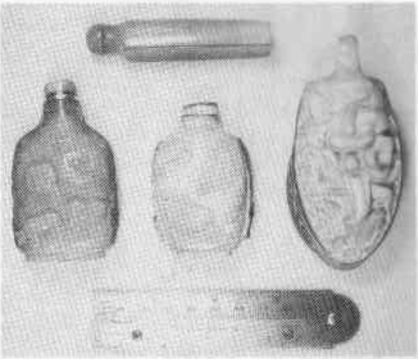


Figure 3

His approach was certainly a reasonable one, but we believed him to be in error. The inclusions shown in *Figure 4* strongly resemble, in certain respects, the "moss" in moss agate, which is usually manganese oxide. Apparently, this manganese oxide accumulated on the surface of one of the layers as the chalcedony accumulated (perhaps in the form of a silica gel) and penetrated through the surface of the soft layer. Because of the greater specific gravity of the manganese oxide, a portion of it penetrated in the form of the root of the mushroom.

Dodecahedral Inclusion Lines in a Diamond

Recently, we examined a diamond that showed a number of inclusions that appeared to be gas-filled spaces

Figure 4

outlining a dodecahedral growth pattern very effectively (*Figure 5*). A dodecahedral face is shown at the center of the picture near the bottom portion.

Curved Fluorescence in Synthetic Sapphire

We photographed a synthetic sapphire under short-wave ultraviolet light, because we noticed a very strongly curved pattern under this illumination and noted that it was not in the usual completely concentric curvature that we expect in any Verneuil synthetic (*Figure 6*). Apparently, the fluorescence lines did not follow the pattern of the Verneuil growth pattern. We had not encountered anything like it before.

Crystallites in Glass

A glass imitation was examined in the Laboratory. Under magnification

Figure 5

we noticed quite a number of crystallites in a pattern reminiscent of the crystallographic axes of an isometric mineral (*Figure 7*). We did not determine the nature of the crystallized material.

Odd Emerald Inclusions

The number of emeralds and synthetic emeralds that we have been examining seems to be increasing week by week. The problems attendant to identification also seem to be growing apace. Within the last month we examined an emerald that had these properties: refractive indices, 1.571–1.577; specific gravity, 2.68±; inert to long- and short-wave ultraviolet. Fortunately, the inclusions proved that it was a hydrothermal synthetic. It had a very pronounced plane of tiny two-phase inclusions and, surprisingly, semihexagonal fracture tubes that we associate with flux-fusion synthetic emeralds (*Figure 8*). We have no idea of the manufacturer of this material, although it much more strongly resembles the latest Linde hydrothermal

Figure 6

product than anything else we could compare it to.

The most recent interesting natural emerald we have examined was one in which planes of pyrite crystals dominated the inclusion picture. A plane of these inclusions is in focus in *Figure 9*, and a second plane, at an angle to the first, is seen as a plane in the line on

Figure 7

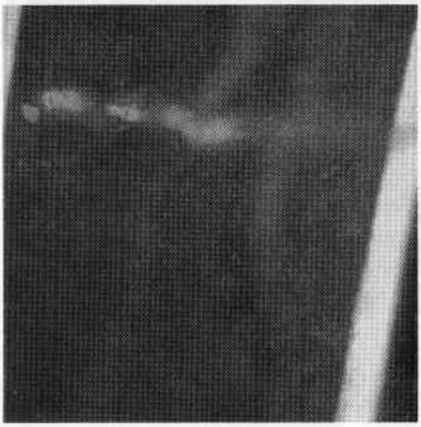


Figure 8

the left side of the photograph, passing through the bright inclusion toward the bottom. When these inclusions were examined at right angles, the hexagonal nature of the planes was evident (*Figure 10*). It can also be seen in the photograph that there was very strong color zoning in the stone. The properties were rather low for natural emerald, with the mean refractive index being approximately 1.57.

Figure 9

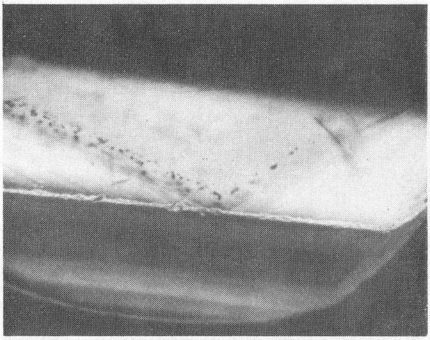


Figure 10

Acknowledgments

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

To **Richard J. Levy**, Los Angeles, for an interesting selection of rough and cut tektites.

To **George F. Harvey**, Gemologist, Denver, Colorado, for an attractive amazonite crystal.

To **Martin Ehrmann**, Los Angeles gem-and-mineral dealer and long-time benefactor, for a selection of cut zoisites, a polished slab of Brazilian agate, rhodochrosite, malachite, apatite crystals and synthetic-emerald crystals.

To Graduate **Ben Gordon**, Gordon Jewelry Co., Houston, Texas, a frequent contributor of stones very useful for test sets, for a large assortment of natural and synthetic stones.

To Graduate Gemologist **Loyd C. Stanley**, C.G., Stanley Jewelers, Little Rock, Arkansas, for a useful collection of assorted stones.

To Gemologist **Edward Hatch** for a nice selection of rough and cut stones.

Book Reviews

PRACTICAL GEM KNOWLEDGE, by Charles J. Parsons, GG, FGA. Published by the Lapidary Journal, *San Diego, California, 1969. 140 pages. Softbound. Illustrated with numerous black-and-white photographs and line drawings. Price: $3.95.*

Practical Gem Knowledge, which was taken, with some revisions, from articles appearing in the October, 1964, to July, 1968, issues of the *Lapidary Journal*, was written by Charles J. Parsons, GG, FGA. He is a retired Navy man who became a Graduate Gemologist after his retirement from the Navy and who, shortly before, assisted GIA instructors in classes in Chicago and Los Angeles.

Parsons is a very knowledgeable gem man who has worked in this field for the past 15 years and who is eminently qualified to write a book on this subject, particularly one keyed to the amateur gemologist, as this one is. He is one of the most respected, even beloved, men in the amateur gem field, particularly in the San Diego area.

The book covers the science of gemology in an easy-to-read, down-to-earth manner, avoiding complicated and cumbersome phraseology. After a discussion of basic terminology, the author discusses physical and optical properties, inclusions, synthetics, imitations, fashioning, testing procedures and gem-testing instruments. This is followed by a discussion of the major gem species and a few of the lesser known gemstones.

Parsons is head gemology instructor for the San Diego Gem & Mineral Society and coauthor of *The Handbook of Gems & Gemology* and *Gem Materials Data Book*.

The book is excellent in its factual presentation. However, the photographs leave quite a bit to be desired, because many of them are lacking in contrast and are unclear. Also, the inclusion of property tables would have been useful. Otherwise, with these exceptions, *Practical Gem Knowledge* is well executed and written and would be a valuable addition to any gem library at such a modest price.

FACETING FOR AMATEURS, by Glenn and Martha Vargas. Published by the authors, 1969. 330 pages. Clothbound. Illustrated with numerous black-and-white photographs and line drawings. Price: $15.

Recognizing the need for a comprehensive book on faceting, the authors present to the lapidary hobby a well-organized and well-written text on all aspects of the craft, including buying and selling rough, orienting before cutting, methods of obtaining the largest and most perfect stone from the rough material, and practical ways of using the many different faceting machines on the market. The book is amply detailed where needed, with simplified and practical explanations of everything needed to inform and teach the student of faceting in this most fascinating part of the lapidary art.

Thirteen chapters comprise the book: Gems & Minerals, Faceting Machines, Laps That Cut, Laps That Polish, Choosing Materials, Optical Properties, Angles for Faceting, Faceted-Stone Patterns, Preparing for Faceting, Cutting the Facets, Polishing the Gem, Soft Materials, and Disposition & Care of Gems. Appendices, a bibliography, a glossary and an index complete the book.

One of the more useful sections of the book is Appendix I, which gives a description of the major gem species, including physical and optical properties, cutting angles, most effective cutting and polishing laps, and miscellaneous information. The cutting advice given here for the more difficult and soft gems can result in the saving of one such stone and more than pay for the cost of the book. Appendix II contains useful tables and formulas.

The authors have had wide lapidary experience. Glenn Vargas, assisted by Mrs. Vargas, has taught general lapidary in the California public schools for 20 years. Part of this experience has been an active business of selling faceting rough. This, together with their faceting achievements and their teaching, has given them an ideal background for the preparation of a book of this kind.

Faceting for Amateurs should be included in the gem library of every person who hopes to master the art of faceting.

METAL TECHNIQUES FOR CRAFTSMEN, by Oppi Untract. Published by Doubleday & Co., Inc., Garden City, New York, 1968. 509 pages. Clothbound. Profusely illustrated with 667 black-and-white photographs and 102 line drawings. Price: $19.95.

Metal Techniques for Craftsmen is the first book that describes in detail the entire art of decorative metal work, offering an exhaustive, illustrated guide for the interested layman, the amateur, and the master craftsman.

In clearly written prose, accompanied by excellent photographs and line drawings, the book presents a step-by-step account of how to form or embellish almost any kind of metal. The text includes full work sequences of objects in the process of creation.

The book is supplemented by a complete index, a section on the use and maintenance of hand tools, tables of weights and measures and other reference material.

Some of the subjects discussed in detail in this comprehensive work include the following: the behavior of metals and their physical properties, the precious metals, the base metals, the ferrous metals, the textures of metal surfaces, punchwork decoration, repoussé and chasing, engraving, etching, applique, Indian decorative techniques, damascene, inlay, hard and soft solders, niello, combining metals with nonmetallic materials, silversmithing, pewter, forging and welding, cold-metal spinning, lost-wax and other casting processes, polishing and coloring.

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