GEMS & GEMOLOGY

VOLUME XXVII

WINTER 1991

THE QUARTERLY JOURNAL OF THE GEMOLOGICAL INSTITUTE OF AMERICA

GEMS & GEMOLOGY

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REGULAR FEATURES

ABOUT THE COVER: Potentially enormous quantities of fine diamonds have been identified off the western coast of southern Africa. The lead article in this issue examines the probable sources of these diamonds and some of the unusual methods being used to recover them from the sea.

The AmFAR Diamond Mask shown here is composed of 936 fine diamonds, weighing a total of 135.9 ct, set in 18K gold and platinum. The largest stone is 3.00 ct. The gold was donated by the World Gold Council and the platinum by Platinum Guild International; the diamonds were provided by the William Goldberg Diamond Corp. Design and fabrication are by Henry Dunay. The mask will be auctioned at Christie's New York on April 14, 1992. The proceeds will go to the American Foundation For AIDS Research (AmFAR).

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Typesetting for Gems & Gemology is by Graphix Express, Santa Monica, CA. Color separations are by Effective Graphics, Compton, CA. Printing is by Waverly Press, Easton, MD.

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Special annual subscription rates are available for all students actively involved in a GIA program. $39.95 U.S.A., $49.00 elsewhere. Your student number *must* be listed at the time your subscription is entered.

Single issues may be purchased for $12.50 in the U.S.A., $16.00 elsewhere. Discounts are given for bulk orders of 10 or more of any one issue. A limited number of back issues of G&G are also available for purchase.

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Gems & Gemology welcomes the submission of articles on all aspects of the field. Please see the Suggestions for Authors in this issue of the journal, or contact the editor for a copy. Letters on articles published in *Gems & Gemology* and other relevant matters are also welcome.

Gems & Gemology is published quarterly by the Gemological Institute of America, a nonprofit educational organization for the jewelry industry, 1660 Stewart St., Santa Monica, CA 90404.

Postmaster: Return undeliverable copies of *Gems & Gemology* to 1660 Stewart St., Santa Monica, CA 90404.

BUYER BEWARE!

What might at first glance appear to be a small item in the Gem News column of this issue raises a very important concern for the gemological community. An experienced colored-stone dealer traveled to Vietnam to obtain some of the new, often spectacular rubies that have recently emerged from this third-world nation (and were described in depth in the Fall 1991 issue of *Gems & Gemology*). He purchased a significant parcel of rough stones, the largest of which was 22 ct. The color and clarity of the material appeared to be superb, although it was difficult to view the interior of the stones because of their "tumbled" exterior and the bits of dirt and matrix that clung to small pits.

When the largest stone was preformed, it became obvious that something was wrong. The dealer immediately sent six of the stones, including the preformed piece, to the GIA Gem Trade Laboratory for identification. Examination with a microscope readily revealed that one of the pieces of rough (the smallest one) was a natural ruby—and that the preform contained the gas bubbles and curved striae typical of a flame-fusion synthetic. Examination of the other pieces was difficult, again because of the rough nature of the exterior; but faint curved striae were determined in two of the stones with magnification. The fact that all but one of the pieces of "rough" submitted were flame-fusion synthetics was confirmed by infrared spectroscopy.

One can only speculate on the loss in dollars, but it is undoubtedly substantial. The owner agreed to share this experience with our readers to reinforce a message that we—at *Gems & Gemology*, GIA, and the GIA Gem Trade Laboratory—have been promoting for decades. Study, examine, learn, KNOW before you buy. While in most cases, when you buy from a legitimate supplier, the supplier will "make good" if the stone is later found to be treated or a synthetic, no such guarantees hold at many of the localities that are producing the finest stones today. And no locality is too isolated to import the synthetic counterparts of their valued gem resources.

Alice S. Keller
Editor

MARINE MINING OF DIAMONDS OFF THE WEST COAST OF SOUTHERN AFRICA

By John J. Gurney, Alfred A. Levinson, and H. Stuart Smith

A vast resource of gem-quality diamonds exists off the west coast of southern Africa. Over the course of millions of years, many diamond-bearing kimberlite pipes in the Orange River drainage basin have been extensively eroded and the released diamonds transported to the west coast. Raised marine deposits now on land have yielded almost 100 million carats of predominantly gem diamonds; similar marine deposits and feeder channels are now known to exist offshore. Techniques for exploiting the offshore resources have been proved on a small scale in shallow (<15 m) waters. New technological developments in underwater mining systems have progressed to the point where mining has commenced in deep (about 100 m) Namibian waters. It is anticipated that production of diamonds from the sea will increase substantially in the future.

ABOUT THE AUTHORS

Dr. Gurney is professor in the Department of Geochemistry, University of Cape Town, Rondebosch, South Africa, and also Chairman of Benguela Concessions (Benco), a company engaged in mining diamonds off the west coast of southern Africa. Dr. Levinson is professor in the Department of Geology and Geophysics, The University of Calgary, Alberta, Canada. Dr. Smith is exploration manager for Benguela Concessions.

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Because diamonds are the heart of the jewelry trade, the continued supply of fine diamonds from the mines into the marketplace is of critical importance to this industry. According to the Central Selling Organisation, about one-eighth (approximately 13 million carats) of the diamonds now mined annually eventually end up in jewelry (figure 1). Yet for the largest producer of diamonds in 1990, the Argyle mine in Western Australia (36 million carats), fine gem-quality diamonds represented only about 5% of the total yield. In addition, older deposits of gem-quality diamonds are gradually being exhausted. For example, the total production at the Kimberley pool of mines was 1,173,042 ct in 1980 but only 574,188 ct in 1990 (De Beers Consolidated Mines Ltd., 1981, 1991).

In the future, the steady supply of gem diamonds to the jewelry industry will depend on the discovery of new deposits and the engineering expertise to extract the diamonds economically. Because the search for new diamond reserves in conventional primary (e.g., kimberlite or lamproite) or secondary (e.g., alluvial) deposits is very expensive and generally has a low probability of success, mining concerns are looking to the extraction of diamonds from known, if unconventional, sources, such as the undersea deposits off the west coasts of South Africa and Namibia.

These exceptional deposits of gem-quality diamonds have been known for some time, but they have not been exploited fully because of the technological difficulties of recovery. Estimates of the amount of diamonds range upward from a conservative 1.5 billion carats, of which approximately 90%-95% are gem quality (Wilson, 1972; Meyer, 1991). Thus, the marine deposits off southwestern Africa apparently contain at least 100 times as many gem diamonds (by weight) as are presently being used annually in jewelry. In addition, this source contains a

Figure 1. This is a representative sample of diamonds produced from concession 6(A) near Koingnaas, South Africa. Most of the diamonds are in the size range 0.1 to 0.6 ct, and exhibit excellent shape and overall quality. Photo courtesy of Benguela Concessions.

high percentage of rough suitable to cut the small ($^1/_4$ to $^3/_4$-ct) gems that are very important in the jewelry industry.

The economic and technological climate now permits mining of these deposits. Although the problems of recovery are major, as will become clear from the discussion below, considerable progress has been made in recent years to establish a viable extraction industry. The financial risks continue to be significant, but the vast reserves hold extraordinary promise.

HISTORY

The first discovery of diamonds related to marine deposition in southern Africa was on land in 1908 near Luderitz, Namibia (figure 2); the history of this discovery is described in detail by Levinson (1983). This led to the subsequent discovery of rich diamond fields along the west coast of then German South West Africa, and the development, within a few years, of a huge industry in this arid, inhospitable region. Later, diamonds were also discovered and mined elsewhere along the vast coastline from south of the Olifants River in South Africa to north of Hottentot Bay in Namibia, a distance of about 1,000 km. Although the great majority have been mined on what is now land (on beaches and raised terraces), the diamonds were originally deposited under water, having been carried

Figure 2. Large quantities of diamonds have been found both onshore and, more recently, offshore the west coasts of South Africa and Namibia. Noted here are the key rivers and towns involved in the distribution and recovery of the marine diamonds.

into the sea by rivers at a time when the oceans were at a higher level.

The significantly more difficult exploration for diamonds on beaches still under water was started by two small companies in 1954. During the period 1961 to 1965, these efforts were greatly expanded by a Texan, Sam Collins, through the Marine Diamond Corporation (MDC). MDC was subsequently acquired by De Beers and is essentially the forerunner of the currently very active De Beers Marine (Pty) Ltd., which now operates prospecting and trial-mining vessels in Namibian and South African waters.

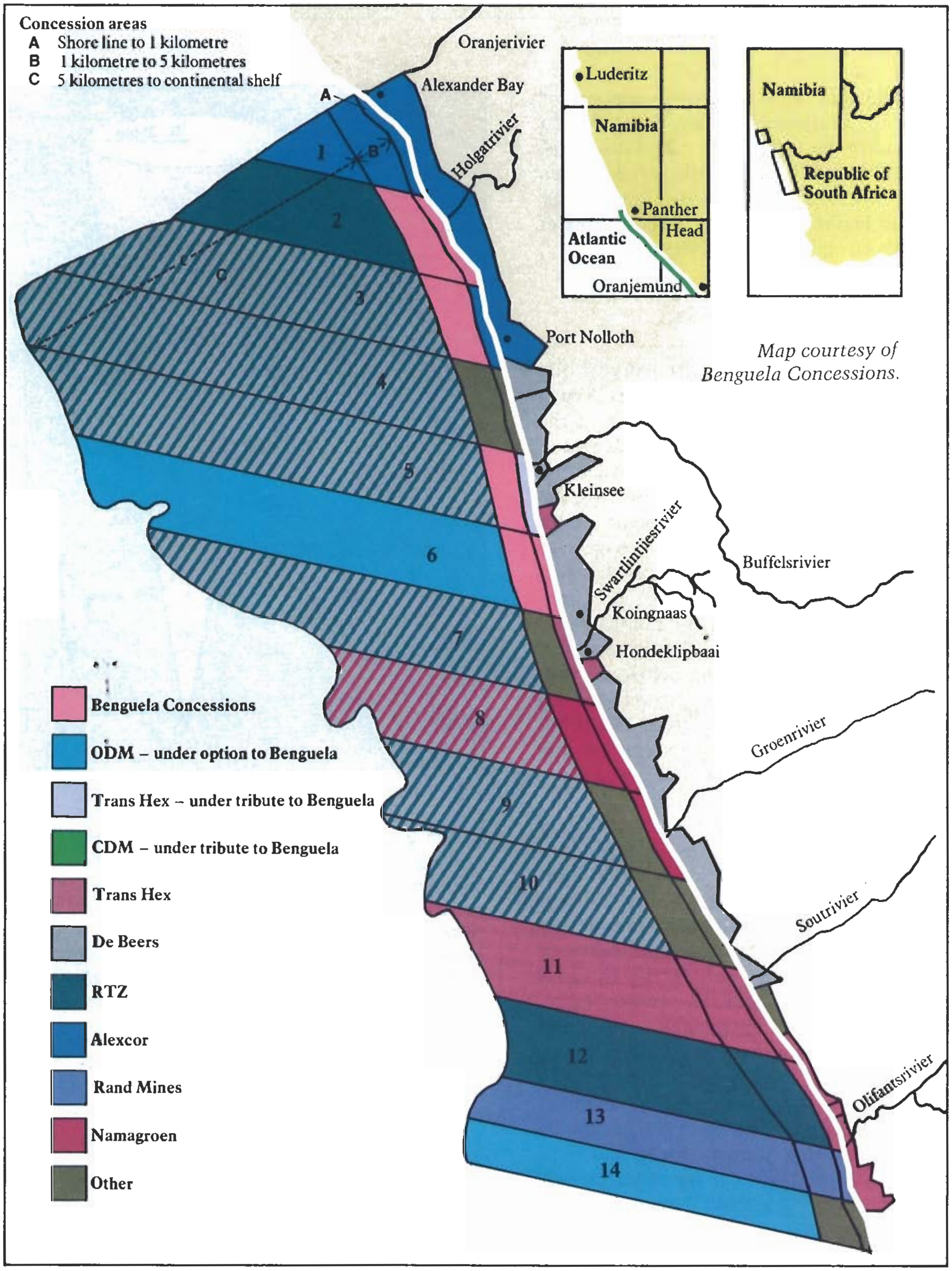
No other mining company in this field approaches the size and scope of De Beers Marine, which dominates the available offshore lease areas of Namibia and South Africa (figure 3) through holdings and joint-venture agreements. In South Africa, the activity of De Beers Marine is confined essentially to water deeper than 100 m (the C concession zones; again, see figure 3).

Two other groups, Alexcor and Benguela Concessions (Benco), accounted for more than 50% of the marine diamonds produced annually from the Namaqualand sea diamond operations in 1989 and 1990. Several minor contractors provide the balance of the production from South African waters. Most of the marine diamonds produced in South African waters (>70% in 1990) are won from gravel recoveries close to the mouths of the Orange, Buffels, and Olifants rivers.

In Namibia, offshore diamond mining is dominated by Consolidated Diamond Mining (Pty) Ltd. (CDM), a wholly-owned subsidiary of De Beers Consolidated Mines Ltd., which controls those offshore mining areas from the mouth of the Orange River to Luderitz (Dias Point) that lie within Namibian territorial waters. CDM also controls areas farther north, notably at Hottentot Bay.

The Namibian West Coast Diamond Company has an offshore diamond-mining area that extends from Dias Point almost to Hottentot Bay, which it works actively on a small scale. In 1990, several other offshore diamond-prospecting leases were granted by Namibian authorities, but no significant recoveries have yet been reported from these new leases.

Ocean Diamond Mining Ltd. (ODM) is entitled to recover diamonds from the territorial waters around 12 small islands off the Namibian coast that belong to the Republic of South Africa. These rights, associated with what are referred to as the "guano islands," belong to Eiland Diamante (a subsidiary of Trans Hex), which entered into an agreement with ODM in the early 1980s that allows the latter to exploit the rights for a small royalty payment.



Map courtesy of Benguela Concessions.

Figure 3. The offshore diamond mining lease areas in South African waters in 1991 are identified. The coastal shelf waters have been divided into 20 contiguous, parallel strips; numbers 1 to 14 (shown here) have been further subdivided into three units (zones)—A, B, and C—according to their distance from the shoreline, in successively deeper waters. Area A is 1 km wide and roughly parallel to the coast, with its inshore boundary 30 m seaward of the low-tide mark. Area B is seaward of A and lies from 1 to 5 km offshore. Zone C comprises the rest of the continental shelf and is in deeper water, generally greater than 100 m. Onshore concessions are also shown, to the right of the thick white (shore) line. Zones with diagonal stripes are controlled by De Beers. The insert of Namibia from Oranjemund to Luderitz shows the area under tribute to Benguela Concessions.

Further details on the historic aspects of marine coastal diamonds off southern Africa may be found in the articles by the Geological Department, De Beers Consolidated Mines (1976), Van Wyk and Pienaar (1986), and Meyer (1991), and in books by Wilson (1982), Levinson (1983), and Joyce and Scannell (1988).

FORMATION OF THE MARINE DIAMOND DEPOSITS

Source of the Diamonds. The discovery of diamonds on the west coast of southern Africa inevitably led to a search for their origin in the immediate hinterland. Only one reputable geologist, ironically the highly respected Dr. H. Merensky, who is credited with discovering the major South African platinum deposits, ever seriously believed that the primary origin for these diamonds was submarine kimberlites in the Atlantic Ocean. All others, particularly consulting geologist Dr. E. Reuning, postulated a primary origin somewhere in the continental interior from which, following erosional processes, the diamonds were transported to the sea by such rivers as the Orange, Buffels, and tributaries to the Olifants. (The literature on this subject is voluminous, but a comprehensive review can be found in Williams, 1932.)

It has long been known that the primary sources of most diamonds are kimberlite pipes intruded into older parts of the continental interior, that is, cratons (for a review of this subject, see Kirkley et al., 1991). Most of the diamondiferous kimberlites in southern Africa are between 80 and 120 million years old. In the interval between their formation and the present, many of these pipes have been extensively eroded and their diamonds released for transportation into secondary (alluvial, beach, etc.) deposits. In some cases, such as around Kimberley, as much as 1,400 m of the original depth of the numerous pipes and surrounding country rocks has been eroded (Kirkley et al., 1991). If we consider only the Kimberley mine ("Big Hole") as an example, and take into account its shape (cone), dimensions (depth of mining, surface area), and amount of erosion since emplacement, calculations (figure 4) show that about 34 times the volume of rock mined has actually been eroded. The volume of rock mined yielded about 14.5 million carats of diamonds before mining ceased in 1914. Assuming that the pipe had a uniform content of diamonds throughout (a conservative assumption because diamond grades tend to increase, and pipes tend to flare out, toward the top), then about 500 million carats were eroded away from this one pipe alone and released into

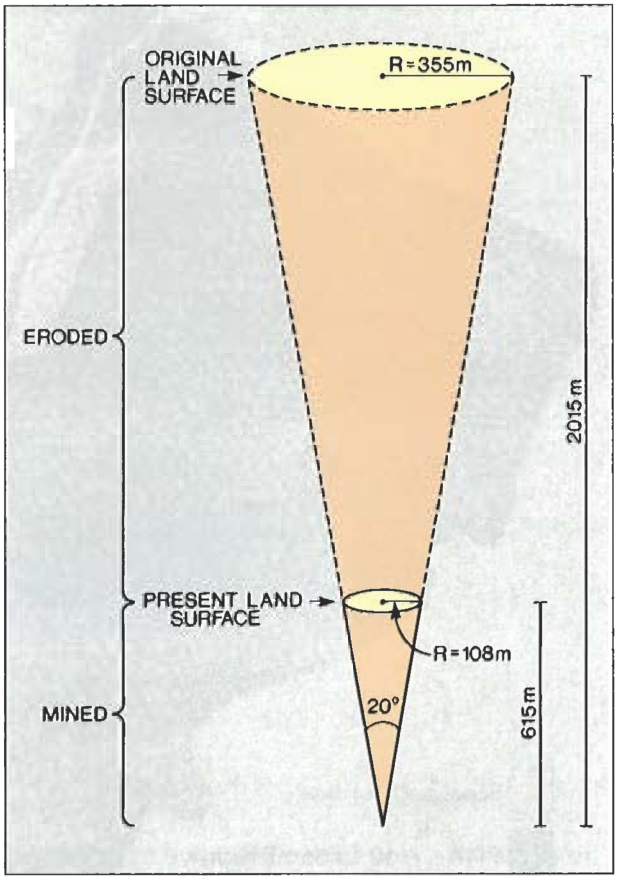


Figure 4. On calculating the volume of rock removed from the Kimberley mine (the "Big Hole") in Kimberley, South Africa, the assumption can be made that the shape of the pipe approximates a cone whose volume can be determined from the formula $V = (\pi/3)R^2H$ *(where R = radius and H = height). For this example, the depth of mining is taken as 615 m and the depth of erosion as 1400 m (2015–615 = 1400). These and other dimensions are shown on the illustration. From these data, calculations show that the volume of rock eroded (about 258 million cubic meters) is about 34 times as large as the volume of rock mined (about 7.5 million cubic meters), which we know yielded about 14.5 million carats of diamonds before mining ended in 1914.*

the drainage basin. There are an estimated 3,000 kimberlite pipes and dikes in southern Africa and, although not all contain diamonds, erosion of their combined original contents (by even the most conservative estimates) is sufficient to far exceed the 1.5 billion carats of diamonds postulated for the marine deposits. This last figure allows for the destruction of many flawed, heavily included, lower-clarity stones *en route* to the sea.

The dominant drainage in southern Africa has been westward since the emplacement of most of the known kimberlites as long ago as 100 million years (Dingle and Hendry, 1984). Currently, sediment transportation from the kimberlites in the interior of southern Africa is confined to the Orange River drainage system (figure 5). However, over time, changes in climate and geomorphology have had dramatic effects on river courses, rates of flow, volumes of runoff, rates of erosion, etc. For at least the last 80 million years, the Orange River has transported sediments from the continental interior to the Atlantic ocean through two main courses, which have led to the deposition of diamondiferous sediments at different positions along the coastline (figure 6). It is likely that, for 45 million years (from 20 to 65 million years before the present), the mouth of the Orange River was located about 400 km south of its current location, in the area that now forms the mouth of the Olifants River (again, see Dingle and Hendry, 1984).

Diamonds have also been transported to the sea along shorter river courses, such as the Buffels, which have cut back into the old interior land surfaces and reworked fossil gravels. Other geologic situations—for example, where small rivers have reworked old exposed beaches to concentrate diamonds into new deposits—are also known but are beyond the scope of this report.

From what has been discussed to this point, it should be clear that alluvial diamonds can be found anywhere along the extensive Orange River drainage basin between the primary kimberlite sources and the point at which the diamonds entered the sea. In fact, inland alluvial diggings have been important in South Africa since the discovery of the primary deposits. Nevertheless, of all the gem diamonds that have been released into the drainage basin and have survived the erosional processes, we believe that less than 10% are on land; the great majority have traveled to the sea.

Marine Distribution. Wave action is a powerful agent for transporting material, particularly on the west coasts of South Africa and Namibia, where the winter months are characterized by

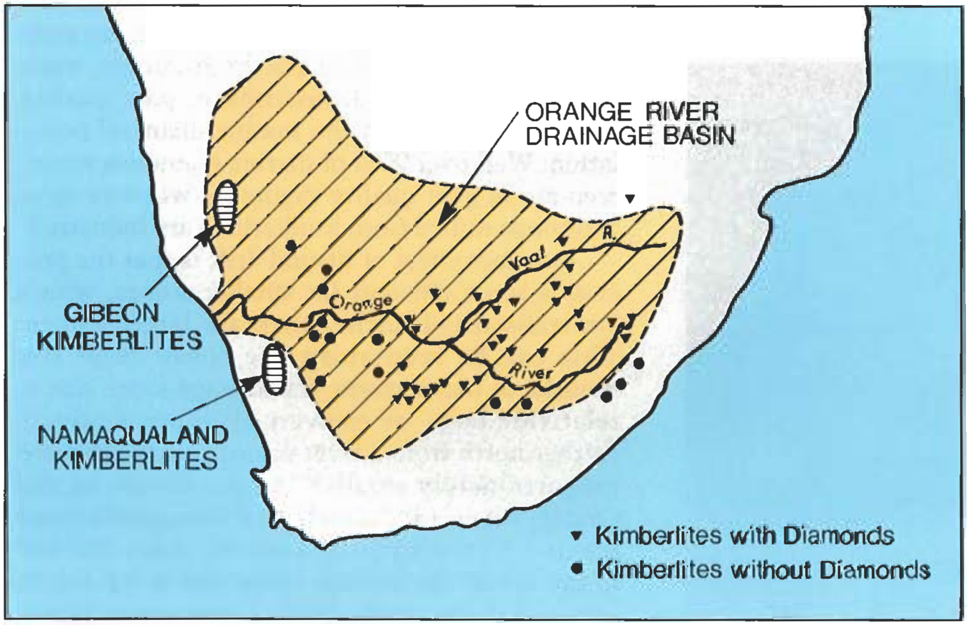


Figure 5. This map of southern Africa shows the present Orange River drainage basin, including the present position of the Orange and Vaal rivers. Also shown are the locations of kimberlites with and without diamonds as well as the Gibeon and Namaqualand kimberlite fields, both of which are barren of diamonds. Alluvial diamonds have been found throughout the drainage basin, but the vast majority have been transported westward to the Atlantic Ocean.

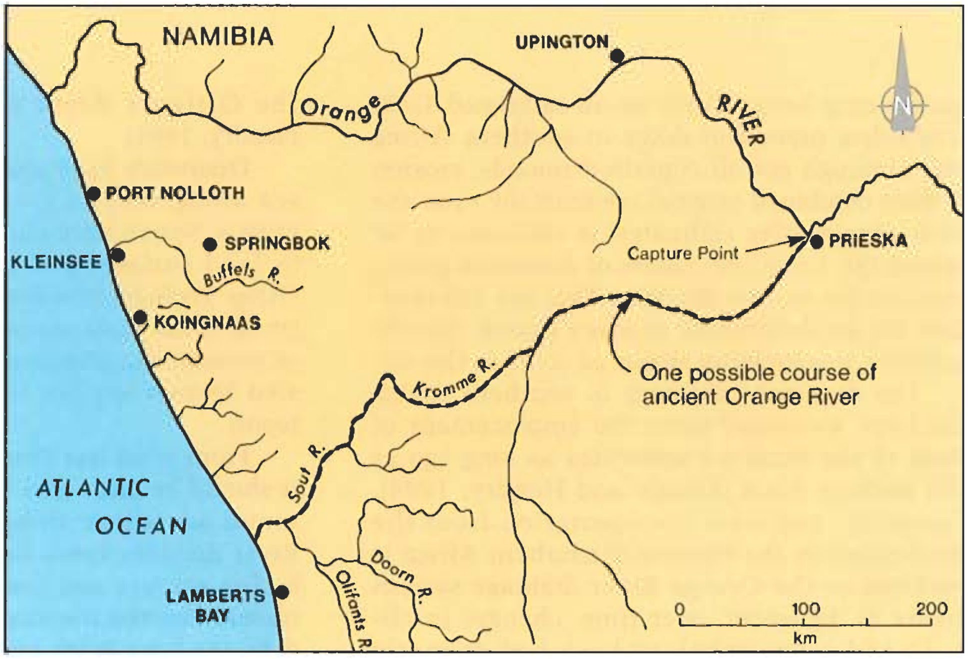
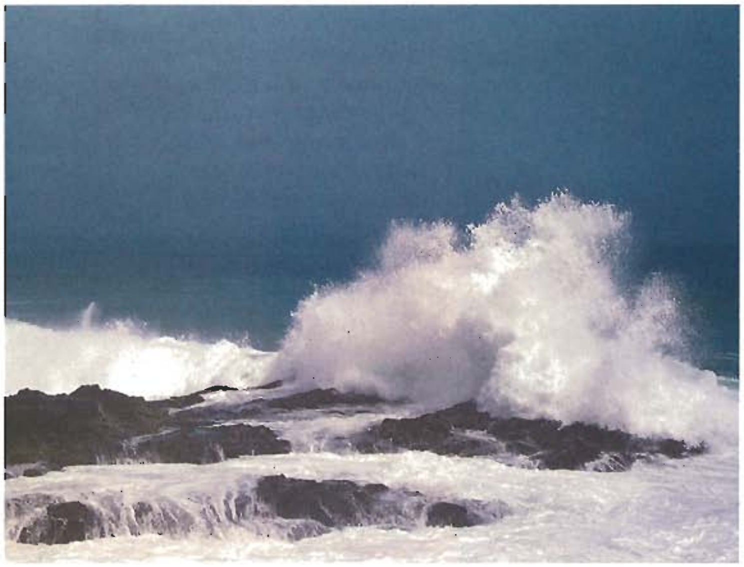


Figure 6. The Orange River drainage system has migrated over time. One possible course in the past is in the vicinity of the present Kromme, Sout, and Olifants rivers. This possible ancient course accounts for marine diamonds being found far to the south of the mouth of the present Orange River.

wild and stormy seas (figure 7). The waves are generated in the South Atlantic and attack the coastline from the southwest, reinforced by the prevailing southwesterly wind. This results in a strong northerly littoral (i.e., along the shore) drift of sediments.

Figure 7. The typical wave action seen here along the west coast of South Africa (in concession 9A) illustrates the powerful force that continually moves the diamonds northward along the shore.



This wave and wind regime has existed along the west coast of southern Africa for millions of years. Thus, littoral drift has played a major role in distributing diamonds along the coast. Coarse sediment (sand and gravel plus diamonds) transported to the sea by rivers is steadily moved northward from the mouths of those rivers. As diamonds are chemically inert and hard, they are only minimally subject to mechanical abrasion or weathering during transportation along the coast. On the other hand, poorly shaped and strongly fractured stones that survived river transport to reach the ocean are preferentially destroyed in the high-energy wave environment. This destruction of poor-quality stones is reflected in the marine diamond population: Well over 90% of marine diamonds recovered are of gem quality (figure 8), whereas most diamonds mined from kimberlites are industrial.

Another effect of littoral drift is that the process is more efficient for smaller stones, which are transported further than are larger stones. This can be seen along the coast: Near the mouths of major rivers, the average stone size is relatively large; at recovery sites progressively further north from a river mouth, stone sizes are proportionately smaller. At the mouth of the Orange River, for example, the average diamond size is 1.5 ct, whereas at Luderitz, some 200 km to the north, the average stone size is 0.1–0.2 ct (figure 9; Sutherland, 1982). Large stones found at the mouths of the Olifants, Groen, and Buffels Rivers are similar in size to those found at the mouth of the Orange River. Thus, the diamonds are sorted and sized during, and as a result of, marine transportation subsequent to their initial deposition into the ocean.

Diamonds have a higher specific gravity (3.52) than do most common minerals (e.g., quartz at 2.66) and rock pebbles. Consequently, they tend to gravitate, along with other relatively heavy minerals, to the base of trap sites such as gullies, potholes, south-facing bays, and old beach levels (figure 10). In some instances, spectacular grades occur where the sea has concentrated thousands of carats of diamonds in very small areas. In general, the smaller the average size of the diamonds, the more evenly the stones are distributed over a beach level. Bigger diamonds are sometimes found in "jackpot" trap sites—usually small, very specific features with only a few cubic meters of gravel (again, see figure 8). Although the smaller diamonds are less valuable, they are more abundant.

Sea levels have fluctuated widely in the last 100 million years or so, from more than 500 m below present levels to 300 m above present levels (figure 11; Siesser and Dingle, 1981). During times when the sea level was significantly lower, rivers flowed across the now-submerged continental shelf off South Africa and Namibia, and diamonds were transported to the then-prevailing beaches. About 25 million years ago, when the sea level was about 500 m lower than it is now, some of these beaches were as much as *several hundred kilometers* into the Atlantic Ocean compared to the position of the present shoreline, because much of the continental shelf was exposed. Littoral drift processes similar to those that operate today distributed diamonds along the ancient coastline. Where the sea level remained constant for some time, wave-cut cliffs and terraces formed, as did sites in which diamonds could be trapped (again, see figure 10). Today, there are at least eight different levels—ranging from 20 to 120 m—below modern sea level, in which persistent wave-cut terraces can be traced over much of the length of the west coast of southern Africa; all potentially hold diamonds.

Beaches that formed when sea levels were higher than today are currently exploited for their diamonds. In Namibia, for example, CDM is presently mining (or has mined) at least four

Figure 8. These two 2.6-ct. diamond octahedra were obtained near the mouth of the Olifants river in 1984. Note their clarity, excellent crystal shape, and the absence of abrasion marks. These diamonds may have traveled more than 1,000 km from their kimberlite source to the sea.

Figure 9. This diagram shows the decrease in the size of diamonds recovered from beach sands from the mouth of the Orange River northward (modified from Sutherland, 1982). The dotted line represents the theoretical decrease in size with distance; the solid line represents the actual distribution pattern. From this it can be seen that the size of diamonds recovered from the sea off Namibia varies with location. (This generalization is not always applicable in South Africa for several reasons, for example, reworking of some deposits by smaller rivers presently crossing the diamondiferous beach sands and terraces.)

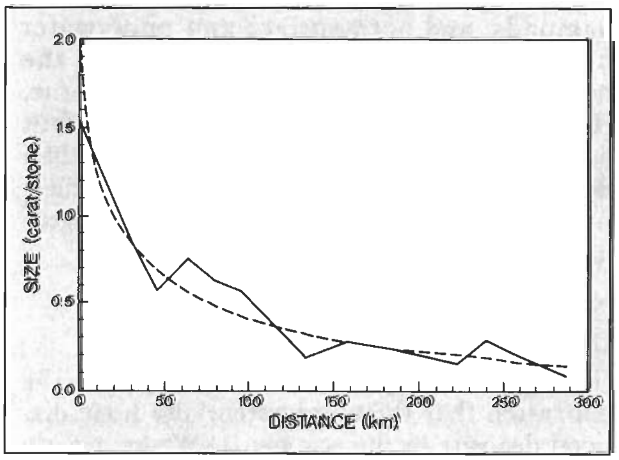


Figure 10. Rich deposits of gem-quality diamonds were concentrated in potholes such as these on a beach terrace at Kleinsee, South Africa, as a result of the relatively high specific gravity of diamonds and their other physical properties (e.g., their durability, which enables them to be transported long distances without being destroyed). Similar potholes and areas of diamond accumulation occur under the sea.

exposed beach levels that extend to 90 m above sea level. In South Africa, in the region between the Orange River and Port Nolloth, diamonds are present in raised beaches at seven elevations ranging from 9 to 84 m (Geological Department, De Beers Consolidated Mines, 1976, p. 27). It was in this coastal area that a 211.3-ct diamond was recovered. The modern beach level and associated terrace is also well mineralized with diamonds, and both surface and underwater mining operations occur from south of the mouth of the Olifants River to north of Luderitz. Thus have sea-level variations and littoral drift distributed diamonds over the continental shelf off the west coast of southern Africa, making it in all probability the greatest resource of gem diamonds in the world.

EXPLORATION, RECOVERY, AND NEW TECHNOLOGY

The captivating questions that follow on the realization that there are potentially huge diamond deposits in the sea are: (1) Where exactly are the diamonds located? and (2) Can they be recovered economically?

The marine deposits can be conveniently divided into two zones on the basis of their depth beneath the water (these zones should not be confused with the A, B, and C zones used in connection with leasing concessions; see figure 3). Those in water shallower than 15 m are being very actively reworked by waves and currents. Those in deeper water are today preserved as "fossilized horizons" (stable locations unaffected by waves and currents). The practical reason for recognizing these two zones is that divers can operate for extended periods of time in shallow water without the need for sophisticated equipment, whereas in deeper water such is not the case.

Since the late 1970s, independent divers have been recovering small volumes of gravel from favored trap sites in shallow water all along the western seaboard of southern Africa (figure 12). In the process, they have demonstrated the presence of rich concentrations of diamonds from the mouth of the Olifants River in the south to Hottentot Bay north of Luderitz. These gravels have been recovered by the divers (figure 13) using suction-pump equipment mounted on tractors on beaches and rocky promontories (figure 14), or on small boats (figure 15). On several

Figure 11. Over the last 70 million years, the sea level off southern Africa has fluctuated from more than 500 m below present levels to more than 300 m above. The dashed portion of the line indicates uncertainty. Modified from Siesser and Dingle (1981).

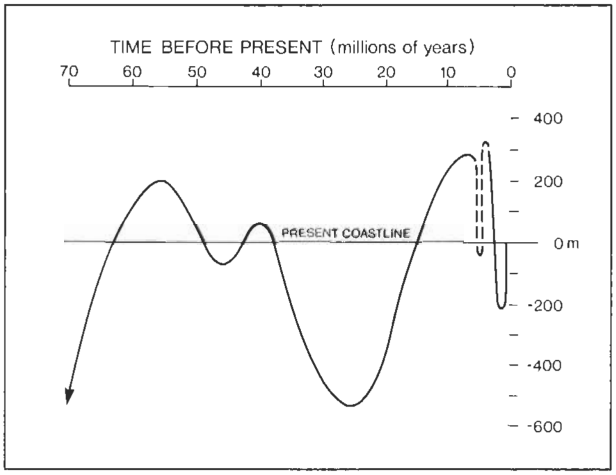


Figure 12. Independent diver Colin Walker enters the ocean to start work in shallow-water concession 12A. Just to the right of this photo, the two diamond octahedra shown in figure 8 were recovered from a cave worn under the cliff.

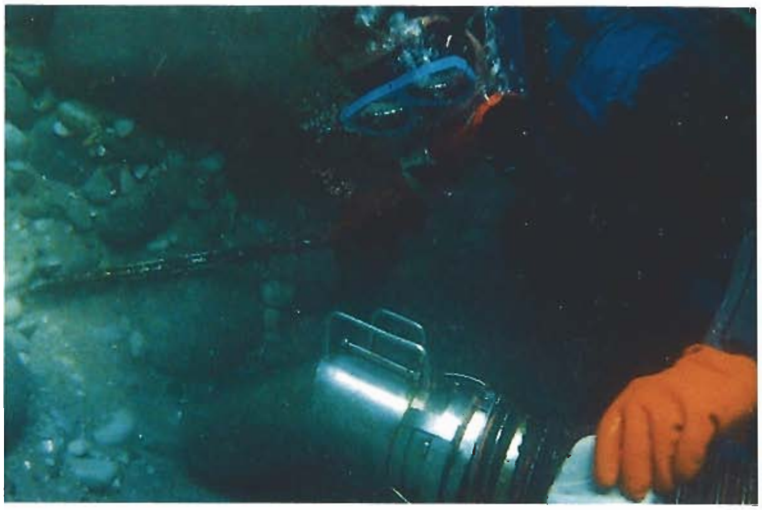


Figure 13. A diver in a heavy-duty wetsuit and 50 kg of lead weights recovers diamonds from gravels in the shallow zones by means of a vacuum hose connected to on-shore suction pumps.

Figure 14. The other end of the suction apparatus illustrated in figure 13 is frequently mounted on a tractor (which supplies the power) that is located nearby (here, far upper right) together with a sieving operation. The sack in the foreground contains diamond-bearing material that has been screened to eliminate the coarse gravel. This "sieved material" will be taken to a diamond-recovery plant for further processing.

Figure 15. The harbor and village of Port Nolloth are home to numerous small boats used in offshore diamond mining. Most of the boats seen here are converted fishing trawlers, each equipped with a decompression chamber as well as with two 20-cm pumps to recover gravel. Divers who work from these boats use gas mixtures and heated diving suits that enable them to dive as deep as 40 m. Most of these boats, as well as the harbor facilities, are owned by Benguela Concessions.

occasions over the past 15 years, individual pump sites have yielded over 1,000 ct of diamonds from less than 10 cubic meters of gravels. Certain individuals have made themselves famous and wealthy by their ability to find these jackpots. Brian MacFarlane, Colin Walker, Jackie Du Toit, Willie Strydom, Davey Clark, and Paul van Gyssen are legendary for their ability to prospect and work the gravels on different parts of the coast.

This level of activity in the shallow zone (<15 m), however, is not likely to flood the world market with diamonds. Even in a record year such as 1990, only 127,000 ct of diamonds were recovered by these methods, and the prospects for improving on this figure are limited.

The real potential lies in the deeper water, where it is possible to explore systematically for the hidden gemstones. For practical purposes, these deeper waters can be divided into two zones (again, not to be confused with the concession zones delineated in figure 3): (a) water depths of 15 to 40 m, in which exploration activities, including sampling, can be carried out with existing technology; and (b) water depths in excess of 40 m, in which more advanced equipment is needed (Benguela Concessions, 1991).

Exploration in these two zones initially takes the form of a geophysical survey that uses sophisticated position-fixing and data-gathering equipment to produce the equivalent of an aerial photograph of the sea floor on which can be superimposed a number of remote-sensing measurements. Such surveys are costly ship-borne operations that are best carried out in good sea conditions.

The amount of detail that can be recorded and interpreted has escalated by leaps and bounds in recent years through computerization of data bases, satellite navigation, and marked improvement in the sensitivity of geophysical equipment. Not only can submerged river channels and deltas, cliff lines, and storm beaches be readily identified, but individual gullies, basin-shaped deposits, and even fossil ripple marks in gravels—the types of features that could contain diamonds—can also be recognized and located again easily.

The next step in the exploration for deep-water deposits is to sample these features to establish whether or not they are mineralized. This can be done in a number of ways. Divers can be used, but at these depths they require expensive diving aids such as decompression chambers, mixed gases, hot-water suits, and ship-to-diver communications. Diving is also a slow procedure. In contrast, devices such as airlifts, underwater robots, or jet pumps can be custom designed for the job. These can handle much higher volumes of gravel but, unlike a diver, they are not so flexible when it comes to recovering gravel from narrow gullies, geometrically complex potholes, or extensively gullied terrain. Since diamonds often concentrate on such bedrock features in alluvial processes, this is a vital consideration. Recent developments, which include the use of high-pressure water jets to liberate gravel trapped in boulder beds, have shown considerable ability to deal with this problem.

Following exploration and sampling in the deeper-water areas, mining must follow the high-tech route rather than use divers. The west coast of southern Africa has no deep-water harbors other than Cape Town and Luderitz, so ocean-going vessels that can stay at sea for extended periods must be used. Because such boats cannot derive sufficient revenue from the small volumes of gravel recovered by divers, robotics of some sort are mandatory (figure 16). Some of the boats contain full facilities to separate and sort the diamonds.

Figure 16. This is an example of a robotic bottom crawler. It has a suction-type "cutter head" to raise the gravels, as well as cameras for eyes, lights for 24-hour operation, and a 500-m–long umbilical cord to the mother ship. The robot is controlled by an operator on board the ship; divers are used only for inspection purposes and sea-bottom repairs. Such robots can operate 22 hours a day and pump more than 100 cubic meters of suspended solids per hour. This contrasts with the performance of a diver-manipulated pump (see figures 13 and 14), which may produce two or three cubic meters per day in good sea conditions.

CURRENT DIAMOND MINING AND EXPLORATION IN THE SEA

De Beers Marine has been investigating these offshore deposits, and continuously upgrading their activity, for more than 20 years. According to De Beers Consolidated Mines (1990), they currently have in operation four exploration vessels (engaged in prospecting, sampling, and geophysical surveys) and three mining vessels: Louis G. Murray, Coral Sea, and Grand Banks. Clearly, the allocation of such substantial resources indicates a commitment to the recovery of diamonds from the sea based on confidence in the size of the reserves and the technological feasibility of the recovery processes. The current status of the mining of marine diamonds in the territorial waters of Namibia and South Africa follows.

Namibia. After many years of preliminary work, DeBeers Marine (subcontracting to CDM) has begun the trial mining of areas of the sea floor that have been proved to contain significant quantities of diamonds. Custom designed for this purpose, the Louis G. Murray made significant recoveries of diamonds in both 1989 (21,545 ct) and 1990 (29,000 ct), as noted by De Beers Consolidated Mines (Pty) Ltd. (1990 and 1991). At the present time, with two other mining vessels, the Coral Sea and the Grand Banks, De Beers is forming the nucleus of a mining fleet in Namibian waters. This is expected to be a deep-water operation (> 100 m in depth) owing to the fact that some ships (e.g., the Coral Sea) are capable of operating in depths as great as 200 m (De Beers Centenary AG, 1991). In the foreshore (that part of the beach uncovered at low tide), the recent policy of Consolidated Diamond Mines (Pty) Ltd. has been to use massive engineering projects (e.g., "sea walls") that allow temporary reclamation of the surf-zone sea floor for mining purposes or, alternatively, to employ subcontractors who practice the small-scale recovery methods described above.

The Namibian West Coast Diamond Company, based in Luderitz, recovers diamonds from shallow water using shore-pumping units and small boats, and they are actively prospecting in deeper water. They recovered approximately 30,000 ct in 1990. Ocean Diamond Mining Ltd. (ODM) has undertaken extensive prospecting and trial mining within their lease areas over the past decade, with some success. They are currently investigating options to expand the scope of their activities.

No diamond recoveries are being made from other diamond lease areas north of the Orange River at this time. The total amount of marine diamonds recovered in 1990 off Namibia (excluding onshore recoveries) is on the order of 75,000 ct.

South Africa. Today, the interests of De Beers Marine in South African deep-water lease areas are considerably larger than is shown in figure 3, since the company has entered into various agreements with other lease holders, notably Tinto Africa Exploration (RTZ), Three Sea (Pty) Ltd., and Namagroen Eight Sea (Pty) Ltd. De Beers Marine has an extremely active prospecting program based in Cape Town that involves geophysical mapping and sediment sampling. The remaining deep-water concession holders have their own prospecting programs, but they are currently less active. There is no regular diamond production yet from any deep-water areas, but that is expected to change if De Beers Marine is successful in its major sampling effort in the Namaqualand joint venture areas (De Beers Consolidated Mines Ltd., 1991).

There are also prospecting programs in the B concession zones (again, see figure 3), which can have depths greater than 40 m; Benguela Concessions is currently the most active company. Again, mining operations cannot develop further until the technical problems of mining diamonds underwater by mechanical means, such as by use of robotics, airlifts, or other devices, are resolved so that larger-scale recoveries can be achieved. Consequently, there is also little diamond production from mid-water areas at the present time, although sampling has proved that concessions 2(B), 3(B), 4(B), and 5(B) have sites with economic diamondiferous gravels in places.

In contrast, diamonds are actively recovered from all the shallow waters in concessions 1(A)–13(A). Some areas have been more rewarding than others, notably concessions 1(A), 2(A), 5(A), 6(A), and 12(A), whereas no significant quantities of diamonds have been recovered south of 13(A) to this time. In 1990, the combined production of all operating companies reached a record total of approximately 128,000 ct. Conservatively, this production would exceed $23,000,000 in value.

CONCLUSIONS

A unique combination of geologic and geographic (climatic and geomorphologic) factors has resulted in the concentration of an estimated 1.5 billion carats of gem-quality diamonds in the sea off the west coasts of Namibia and South Africa. These factors include: (a) the occurrence of many diamond-bearing kimberlite pipes in the present

Orange River drainage basin; (b) the extensive erosion of these pipes over the last 100 million years; and (c) the consistent drainage of the present and ancestral Orange River westward into the Atlantic Ocean. Wave and wind action, and littoral drift to the north, have resulted in a predictable distribution of diamonds with respect to size. These marine deposits are probably the largest known resource of gem-quality diamonds in the world. However, large-scale recovery of the diamonds from beneath the sea poses major engineering and mining problems. Nevertheless, the prognosis is good for the economic success of the venture, despite the technological challenges, thus ensuring a significant component of the world's future requirements for gem diamonds.

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SUNSTONE LABRADORITE FROM THE PONDEROSA MINE, OREGON

By Christopher L. Johnston, Mickey E. Gunter, and Charles R. Knowles

The Ponderosa mine is now producing commercial quantities of the gem-quality labradorite feldspar known as sunstone. This gem material exhibits unique optical and physical properties that include a wide range of saturated body colors, aventurescence, and strong pleochroism. The feldspar is An_{70} *labradorite, a high calcic plagioclase; the aventurescence-causing inclusions have been identified as pure native copper. Microprobe analyses conducted on colorless, red, and green samples did not reveal any obvious causative mechanism for the exhibited colors, although ongoing research is investigating intervalence charge transfer, possibly involving colloidal copper. Gemological identification involves the use of R.I., S.G., and microscopy. Locality determination (Oregon) is based on the copper inclusions and a distinct pleochroism.*

ABOUT THE AUTHORS

Mr. Johnston is a graduate student at the University of Idaho, Moscow, Idaho, as well as general partner and mine geologist at the Ponderosa mine. Dr. Gunter is assistant professor of mineralogy at the University of Idaho, and Mr. Knowles is a supervisory geologist and a senior researcher for the Idaho Geologic Survey, Moscow, Idaho.

Acknowledgments: C. Johnston would like to thank Larry Gray, Dr. G. A. Rossman, Dr. D. Peacor, and Charles and Virginia Weightman for their ongoing support.

Gems & Gemology, Vol. 27, No. 4, pp. 220–233

In 1985, the Oregon legislature named the gem variety of labradorite called sunstone as the state gem. Currently, there are two known (and one reported) deposits of this gem mineral in Oregon: the initial discovery 33 km north of Plush in Lake County, south-central Oregon, which has been alternately referred to as the Plush, Lakeview, Rabbit Hills, or Rabbit Basin location; a small deposit reported near the White Horse Ranch in southeastern Harney County, in south-central Oregon; and the Ponderosa mine, in northwestern Harney County. The geology and mineralogy of the Plush deposit have been reported in varying detail by a number of researchers (Powers, 1932; Stewart et al., 1966; Peterson, 1972; Pough, 1983; and Hofmeister and Rossman, 1985).

The Ponderosa deposit was discovered in the summer of 1980, when a logging operation cut roads through the area. Lode claims were staked and pick-and-shovel mining activities began that summer. Mining activity has accelerated since then, and heavy equipment has been added to refine the extraction process. To date, 400 kg of gem-quality rough sunstone have been removed from the Ponderosa mine, 140 kg in 1991 alone. As a result, Ponderosa mine sunstone—in a variety of colors—has begun to find its way into the general gem and jewelry market (figures 1 and 2).

Extensive study of the Ponderosa mine sunstone labradorite has revealed a number of distinctive characteristics, including aventurescence and pleochroism, as well as provided information to help determine the cause of the different colors. This sunstone can be readily identified on the basis of its gemological properties.

LOCATION AND ACCESS

The Ponderosa mine is located in northwestern Harney County, approximately 330 km (220 mi.) west of Boise,

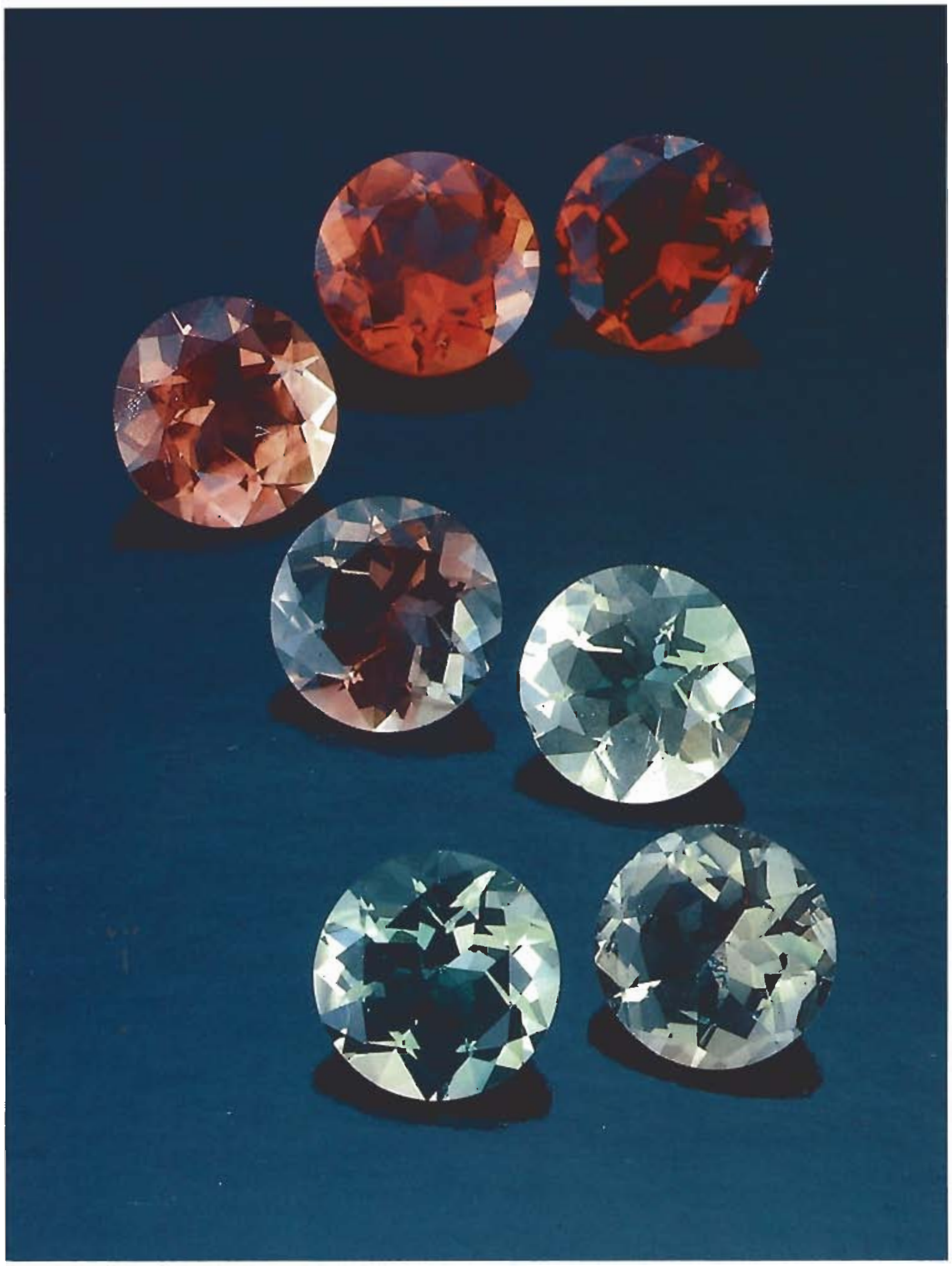


Figure 1. Gem-quality sunstone labradorite occurs at the Ponderosa mine, Oregon, in a broad range of colors, from pale yellow through pale pink to dark orange and even a deep red. The rarest material is green. These stones average 0.40 ct. Photo © Tino Hammid.

Idaho, 255 km southeast of Bend, Oregon, and approximately 60 km N10°W of Hines, Oregon, in the Ochoco National Forest (figure 3). Access to this commercial gem-mining operation is restricted.

GEOLOGY AND OCCURRENCE

The labradorite occurs in a small, localized, weathered basalt flow that is part of a classic volcanic highland typified by shield volcanos, cinder cones, large bodies of ashfall tuffs, regionally extensive basalt flows of varying thicknesses, and locally extensive red cinder beds. The terrain near the mine consists of gently undulating hills covered with ponderosa pines interspersed with large flat meadows. The Ponderosa mine is located at the 1,753 m level on the southeastern flank of Donnelly Butte, the summit of which is the highest local elevation, at 1,856 m. The geology and geothermal resources of the southern half of the Burns 15-minute Quadrangle mapped by Brown et al. (1981) did not include the area of the Ponderosa mine, so its relationship to the regional geology is still largely unknown.

Locally, there are four basalt flows and one welded tuff exposed in section at Donnelly Butte. For the purpose of this article, the five rock groups exposed at Donnelly Butte have been informally designated basalts a, b, c, d, and tuff 1. Basalt a is exposed in the meadow at the base of Donnelly Butte, flow d is in contact with tuff 1 approximately two-thirds of the way up Donnelly Butte, and tuff 1 forms a cap at least 100 m thick on the upper flanks

Figure 2. Ponderosa mine sunstone is now appearing in the international jewelry market. Tiffany produced this 29.78-ct cabochon ring set in silver as part of a line of sunstone jewelry the firm will be promoting. Photo © Tino Hammid.

and summit of the butte. The contacts between the four flows are characterized by the scoria on top of each flow and by intraflow lithology. (*Scoria* is a volcanic slag or pyroclastic ejecta, partly crystalline and partly glassy, that forms as the molten rock degases and creates a froth.) Basalt b (figure 4) is so far the only flow at the Ponderosa mine that contains large gem labradorite phenocrysts.

There are only minor physical and chemical differences between basalts a, b, c, and d, other than alteration and weathering effects. Flow b is thicker (25-30 m) than the other three flows (15-20 m each) and has a more scoriaceous and porphyritic character. Field studies indicate that portions of flow b have undergone extensive weathering or alteration. It is not known whether this alteration is the result of true secondary hydrothermal alteration; of molten rock interaction with groundwater or standing surface water at the time of extrusion; or of flow b being a water-affected-basalt (Jenks and Bonnichsen, 1989). Flows a, c, and d and the non-gem-bearing, non-weathered portion of flow b, on the other hand, exhibit limited or minor weathering. When rock is exposed to hydrothermal fluids, a suite of secondary minerals is normally associated with the interaction of the hot fluids and the host rock. However,

Figure 3. This map shows the location of the Ponderosa mine in northwestern Harney County, south-central Oregon. Also noted are the Plush and White Horse mines. Map by C. Johnston and M. Gunter.

with the exception of one hand-size specimen that shows an encrustation of botryoidal chalcedony, there is no evidence of hydrothermal alteration. The physical evidence that flow b is a water-affected basalt is a little stronger, given the weathering character and amounts of clays present as feldspar alteration (Jenks and Bonnichsen, 1989).

The age of the Ponderosa mine rock section has not yet been determined, but the Lakeview occurrence has been proposed as Steens Mountain equivalent, which is mid-Miocene—approximately 12 million years old (Stewart et al., 1966; Hofmeister and Rossman, 1985). Strike and dip data from flows b and c suggest little or no tectonic displacement.

Flow b is characterized as a moderately to heavily weathered scoriaceous porphyritic basalt, identified as calc-alkaline by whole-rock chemical and electron microprobe analyses. It is composed of labradorite feldspar and basaltic glass, with minor olivine and magnetite/ilmenite present as accessory phases. The vesicles are filled to varying amounts with nonspecific clay and feldspar alteration products. Analysis has shown two distinct size groups of labradorite phenocrysts in flow b: Type L phenocrysts range from 1 cm to 10 cm in length and weigh up to 500 grams; type S are an order of magnitude smaller and dominate the groundmass. Only the type L material has gem potential. To date, mining has shown the gem-quality crystals to be randomly distributed throughout the weathered portion of flow b. Although there appear to be certain trends within the pit where specific grades of gem crystals will occur, no clear model for prediction has been formulated.

The gem-bearing zone in flow b strikes N10°W, with exposures of gem crystals for approximately 700 m along the N10°W trend. The main mine pit is located in the approximate center of this 700-m strike length (figure 5). The gem-bearing horizon exposed in the main pit and downslope to the west is approximately 130 m wide. The eastern extent of the gem-bearing portion of flow b is unknown, as it is covered by the base of flow c. Excavation in the 1991 mining season showed the gem-bearing horizon to be at least 7 m thick in the main pit, with no indications that the bottom of this gem-bearing horizon has been reached. Conservative projections suggest a total reserve of 500,000 metric tons of ore that contain an estimated 200 metric tons of gem material.

At the northern end of the main pit are extremely weathered, strongly altered, gem-bearing zones that are essentially unconsolidated earth (again, see figure 5) with a non-gem-bearing overburden of biota-rich chocolate brown. The groundmass of these in-situ deposits, the depth of which has yet to be determined, is differentiated by its bright reddish brown color and slightly granular texture. Although these zones have produced small quantities of gem material relative to the total overall feldspar phenocryst content (roughly 1 kg of mixed gem-grade materials for every 10 kg of material mined), they are the source of the largest, finest facet-grade gems found thus far, including the 10.79-ct Ponderosa Queen (figure 6). Moreover, to date all of the red-and-green pleochroic material (discussed below) has come from this area.


Figure 4. Sunstone is found only in the heavily weathered basalt flow b. The Jacobs staff is 1.3 m for scale. Photo by C. Johnston

The central area of the main pit contains rock that is less weathered but still strongly altered. This area has consistently produced the finest cabochon-grade gems with deep red body color, as well as most of the smaller (5 ct and under) red facet-grade gems (figure 7).

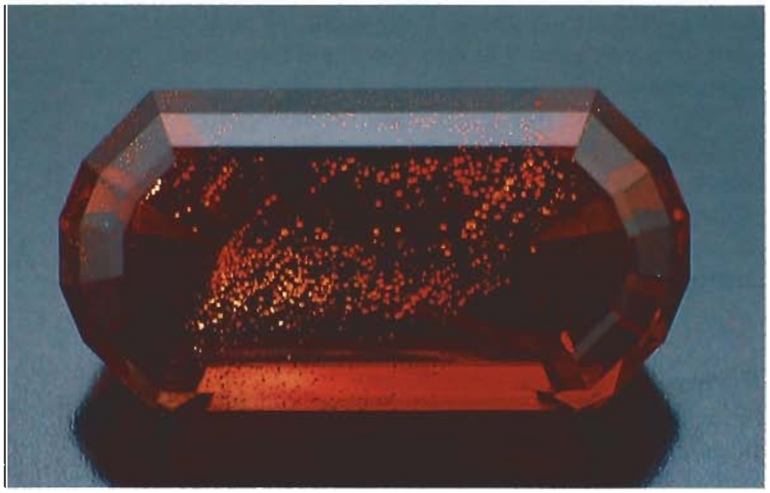
The southern end of the main pit has produced the highest ratio of gem material to total feldspar mined—8 kg:10 kg. However, approximately 85% of the gem crystals have little or no body color. The remaining 15% are small (less than 2.5 ct) red facet- and cabochon-grade stones.

MINING AND PROCESSING

From 1980 through 1988, mining activities at the Ponderosa mine were limited to a series of approximately 12 small hand-excavated prospect

Figure 5. This view of the main pit of the Ponderosa mine is taken from the north looking south. Photo by C. Johnston.

Figure 6. The 10.79-ct "Ponderosa Queen," the largest deep red faceted sunstone in the world, was mined at the northern end of the main Ponderosa pit. Note also that the copper inclusions that cause the characteristic aventurescence of Ponderosa mine sunstone are clearly visible. Photo by Robert Weldon.



pits, most of which never exceeded 5 m^2 and 3 m in depth. In 1989, the transition was made from a manual, pick-and-shovel operation to mechanized mining with a backhoe. By the end of the 1990 season, the pit begun in 1989 was enlarged to approximately 20 m^2 and 5 m deep. In 1991, a bulldozer was used to excavate what is now the main pit, approximately 100 m^2 and 5 m in depth, for which the main ore pile is about 1500 m^3 (again, see figure 5). The estimated gem reserves in all currently stockpiled ore are 1.5 metric tons, or 15,000,000 carats of all grades.

The average mining season is a little more than six months. The 1990 season ran from April 1st through December 15th, limited primarily by daylight and temperature, while the 1991 mining season ran from June 10th until October 15th, owing to snowstorms in June and October. The mine is typically worked by three full-time and two part-time miners.

Gem-bearing material is removed from most areas of the mine with a backhoe in conjunction with a bulldozer, jackhammers, explosives, and hand tools. However, at the northern end of the main pit, where the largest and finest material is usually found, only the backhoe and hand tools are used. As the hardness of the rock increases with depth in the central area of the main pit, jackhammers and explosives are required to loosen the ore.

Once the host basalt has been loosened and the backhoe has loaded its front bucket, it moves to the screening area on the mine dump (figure 8). At this point, the material is slowly loaded onto a one-inch-mesh frame-mounted grizzly for sorting. After inspection, material greater than one inch in diameter is broken down with 5-lb. hammers, since crystals larger than one inch are common. Barren material is dropped off the rear end of the screen complex. The material that passes through the grizzly is conveyed to a 25-ft.-long (about 8 m), inclined, quarter-inch-mesh shaker screen, where the smallest pieces are removed for sorting. Screen fractions greater than a quarter inch and less than one inch are stored at the bottom of the shaker screen and later examined for feldspar crystals. Final screening is done on horizontal, roller-mounted, quarter-inch

Figure 7. This fine 5.04-ct sunstone was found in the central area of the main pit. Photo © Tino Hammid.

Figure 8. For recovery of the gem labradorite, the backhoe moves the loose basalt to the main screening site, where it is transferred to the screen complex (middle background) for initial sorting and then to the inclined shaker screen (right background) for removal of the smallest pieces. Photo by C. Johnston.

screens (figure 9). This final inspection process requires great care, as the feldspar crystals are often difficult to see. Gravity concentration cannot be used, because there is little difference in specific gravity between the waste basalt rock and the gem feldspar.

After the gem material is removed from the horizontal sorting screens, the day's production is tumbled and cleaned. The sunstone is then clipped, using carbide-tipped tile nippers, to remove visible flaws and produce the cleanest possible rough material for cutting. To maximize production, little effort is made to pre-sort the labradorite phenocrysts in the mine pit. After cleaning and tumbling, nongem materials are discarded. The remaining gem material is sorted for facet grade and the finest cabochon grades, as well as according to where it will be cut. Currently, the finest facet-grade rough that will produce finished gems larger then one carat is cut in the United States, as are the finest large cabochon-grade pieces. Commercial sizes and grades of facet and cabochon materials are cut in Asia. All overseas cutting is now calibrated in whole sizes to satisfy manufacturers' specifications.

During the 1991 mining season, daily production averaged approximately 2 kg of all grades. High-grade materials, including top facet and cabochon materials, account for approximately 25%, or 500 grams per day. The remaining 1.5 kg consist of lower grades and smaller sizes of cabochon materials. The average weight of facet-grade rough is 0.5 to 3 grams. The average weight of cabochon materials is slightly larger, at 3 to 5 grams. The largest top red facet-grade rough found to date weighed 15.3 grams and produced a 10.22-ct carving (figure 10) and two smaller stones (2.49 and 3.58 ct). The largest fine cabochon rough produced to date weighed 36.5 grams. Distribution of Oregon sunstone, with the exception of two minor claim holders at Plush, is handled exclusively by the Ponderosa Mine Inc., Boise, Idaho.

Figure 9. Mine owner Larry Gray works the quarter-inch roller-mounted final sorting screens at the Ponderosa mine. Photo by C. Johnston.

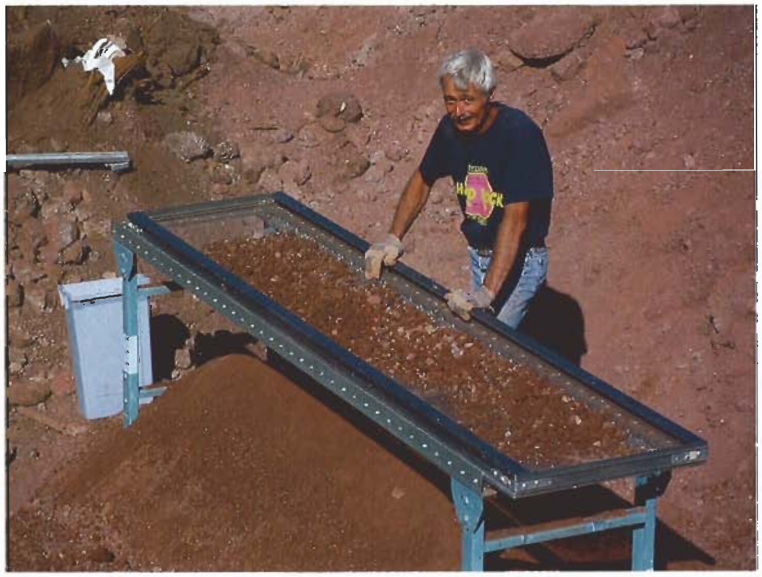


Figure 10. This 10.22-ct carving—the third largest known fashioned red sunstone—is one of three stones produced from the largest piece of facet-grade rough yet recovered from the Ponderosa mine. The rough weighed 15.3 grams. Carving by L. Gray; photo by C. Johnston.

DESCRIPTION OF THE GEM MATERIAL

Chemical (electron microprobe; table 1) and optical (Michel Lévy and spindle stage) analyses have shown that the Ponderosa mine phenocrysts have an albite/anorthite ratio of Ab_{30}/An_{70}, which places the feldspar at the labradorite/bytownite boundary. On the basis of extinction angles and refractive indices (see below), as well as host-rock lithology, the gem phenocrysts from the Ponderosa mine were identified as labradorite.

Crystal Habit. Labradorite is triclinic, for which the only possible crystal forms are pinacoids (forms

TABLE 1. Results of electron microprobe analyses[a] of three Ponderosa mine sunstone labradorites.

Element	Sample[b] 1	2	3	Detection limit
Normalized results (wt.%)				
SiO_2	51.76	52.05	51.52	0.028
Al_2O_3	30.43	29.98	30.61	0.019
FeO[c]	0.38	0.43	0.39	0.061
CaO	14.16	14.23	14.34	0.021
Na_2O	3.18	3.24	3.10	0.022
K_2O	0.04	0.05	0.04	0.021
CuO	bdl	bdl	bdl	0.080-0.092

[a] *Analyses were performed on a JEOL 8600 electron microprobe operating at 15keV with a beam diameter of 0.5 mm; standard ZAF corrections were made; bdl = below detection limits. Ni, V, and Cr were also tested for but not detected above the limits of instrumentation and operating conditions.*

[b] *Sample 1 was transparent and colorless; sample 2 was red; sample 3, green.*

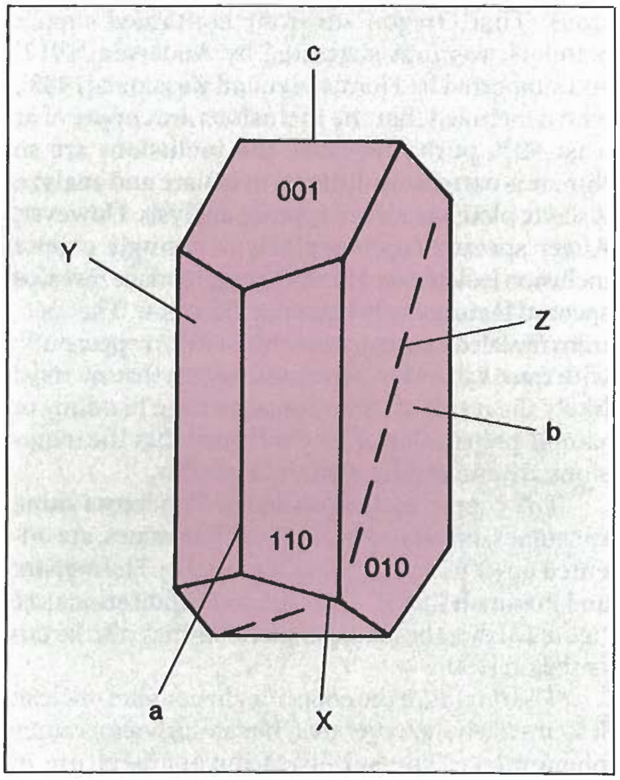
[c] *All iron reported as FeO.*

composed of two parallel faces). Common forms encountered include basal pinacoids {001}, side pinacoids {010}, and front pinacoids {100}. The large type L phenocrysts from flow b at the Ponderosa mine typically exhibit excellent crystal form (figure 11). When phenocrysts are encountered in place in the flow, they exhibit good crystal form. Because of the differential cooling rates between the phenocrysts and the enclosing basalt, however, the crystals are usually fractured; when they are separated from the matrix, they typically come out in fragments.

The labradorite crystals from the Ponderosa mine commonly exhibit albite, pericline, and Carlsbad twinning. Albite twin lamellae are often visible with the naked eye and range from 1 mm to 5 mm in thickness. Carlsbad and pericline twinning are less common and are visible only in thin section.

Aventurescence. All Ponderosa gem-quality labradorite crystals exhibit varying intensities of aventurescence (see figures 1, 2, 5, and 6), a light-reflectance phenomenon caused by the crystallographically planar arrangement of macroscopically visible inclusions (figure 12). Often the intensity of the aventurescence is a direct result of the metallic luster and size of the inclusions, as well as the sheer number present in a given crystal. When present in stones that lack distinct body color, the aventurescence can actually impart a pink or orangy-yellow appearance to the stone. The inclusions in Ponderosa mine sunstone have a large surface area, up to 100 μm in diameter. However, these lamellae have a cross-section of less than 500 nm. Note that, although these inclusions are confined to discrete planes, they are randomly distributed within these planes.

Figure 11. Ponderosa-mine labradorite crystals typically exhibit excellent form. This line drawing shows crystallographic axes (a, b, c) and optical directions (X, Y, Z) of a labradorite crystal.



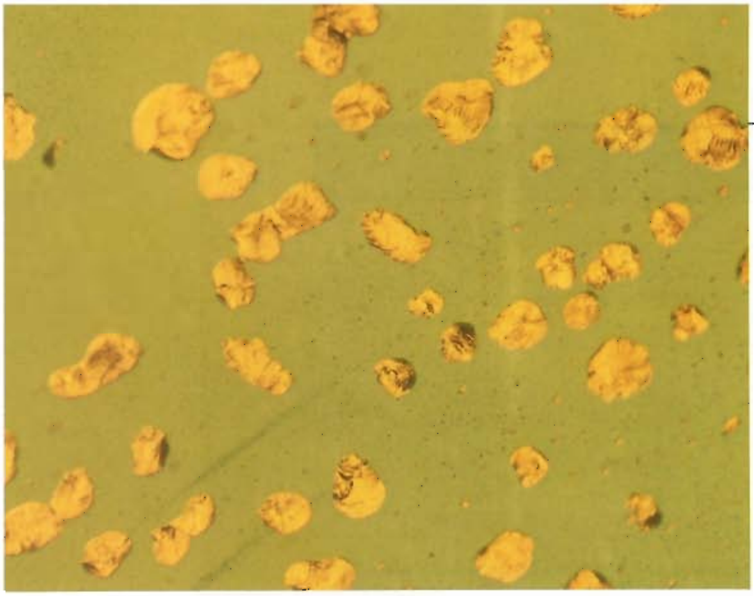


Figure 12. Aventurescence in Oregon sunstone is caused by these metallic-appearing platelets that are randomly oriented within specific planes in the labradorite. The inclusions have been identified as copper. Thin-section photomicrograph taken with reflected light on an Olympus polarizing light petrographic microscope at 50× magnification; by C. Johnston.

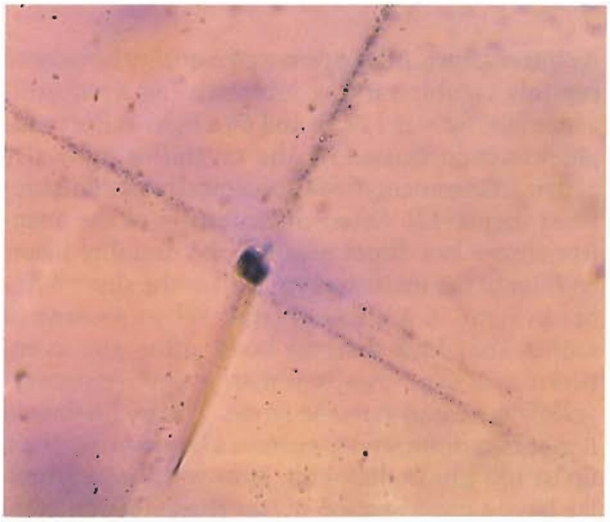
Unique to the sunstones of Oregon is the fact that the inclusions that cause the aventurescence are native copper (again, see figure 12). At other sunstone localities, aventurescence is reportedly caused by hematite (Fe_2O_3; Peterson, 1972) inclusions. That Oregon sunstone contained copper platelets was first suggested by Andersen (1917) and supported by Hofmeister and Rossman (1985), who concluded that the inclusions are copper of at least 90% purity. Because the inclusions are so thin, it is extremely difficult to isolate and analyze discrete platelets for microprobe analysis. However, Auger spectroscopic analysis of a single copper inclusion isolated on a fresh cleavage surface revealed spectral features only from the inclusion. The spectrum revealed a strong (greater than 95%) copper peak, with trace values for carbon and oxygen that are most likely the result of contamination from handling or sample preparation. This confirmed that the inclusions are essentially elemental copper.

The copper inclusions in the Ponderosa mine sunstones, like those in the Plush sunstones, are oriented on (001) and (010), as reported by Hofmeister and Rossman (1985). There are some indications (see figure 13) that these copper platelets may also be oriented on (100).

The origins of the copper inclusions are unclear. It seems likely, however, that they are high-temperature phenomena. The solidification temperature of labradorite is approximately 1200°C, that of copper is 1080°C, and observed extrusion temperatures for Hawaiian Island basaltic eruptions are around 900°C. Further evidence is that $O^{16/18}$ ratios for the Plush location clearly indicate a mantle origin (Rossman, pers. comm., 1991).

The mechanism for precipitation of the copper platelets is straightforward. Based on the overall mineralogy of flow b and the consistency of An/Ab ratios in the feldspar, it seems likely that the melt or magma chamber in which the phenocrysts grew was chemically simple, uniform, and stable for a long period of time. At some time prior to the formation of the type L phenocrysts, the melt absorbed a modest level of copper that was incorporated into the feldspar lattice, where it remained until the pressure and temperature began to drop. As the P/T ratio decreased, the feldspar lattice was unable to hold the elevated levels of copper. Consequently, the copper began to precipitate. (Precipitation, in a mineralogic sense, implies a dissimilar mineral

Figure 13. This photomicrograph of a labradorite phenocryst thin section shows the aventurescent inclusions. The planes of platelets appear to have three axes of orientation: (010) is parallel to the plane of the photograph, (001) is perpendicular to the plane of the photograph and approximately north-south, and (100) is approximately perpendicular to the plane of the photograph and east-west. Photomicrograph taken at 50× magnification under crossed polarized light on an Olympus polarizing light petrographic microscope; by C. Johnston.



phase coming out of solution [not necessarily water] as the result of changing pressure and temperature; D. Peacor pers. comm., 1991). The specific thermodynamic mechanisms and the means of initial platelet nucleation are not known at this time. What is clear is that the physical location of the copper platelets within the phenocrysts was controlled crystallographically, as evidenced by their distinctly planar alignments parallel to crystallographic twin planes (figure 14).

In all cases, sunstones from the Ponderosa mine exhibit copper inclusions. Thus far, we have seen no pieces that appear flawless when examined with 10× magnification. Therefore, the presence of copper platelets can be viewed as a characteristic fingerprint of Oregon origin.

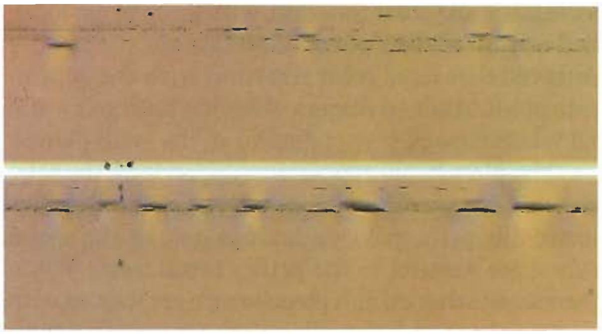


Figure 14. This photomicrograph of a labradorite phenocryst thin section shows the distinctly planar relationship between the copper platelets and the (010) twin plane. Taken at 25× magnification on an Olympus polarizing light petrographic microscope; by C. Johnston.

Color. The Ponderosa mine labradorite crystals exhibit a dramatic range of body colors, including pale yellow, pale yellowish orange, pale pinkish orange, pink, red-orange, deep red, pale green, and blue-green, as well as colorless (again, see figure 1). This range and the generally high saturation of body color are unique to the Ponderosa deposit. Rarest are the bright saturated greens, of which fewer than 20 stones have been recovered each year. Fine saturated green stones rarely exceed one carat, and the largest recovered to date yielded a 1.78-ct round brilliant (figure 15). Only slightly more common—fewer than 30 stones per year—are the bright, sharply bi- and tri-colored stones (figure 16). Much more common are the various shades of red, of which those with a deep uniform red are the most sought after (again, see figures 6 and 7).

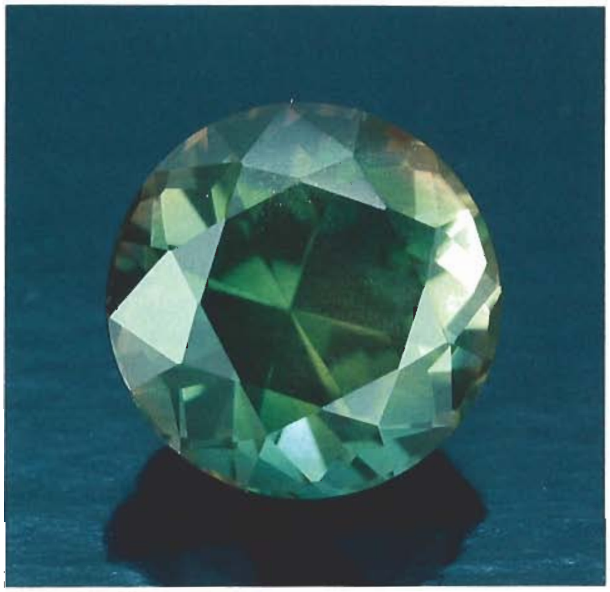
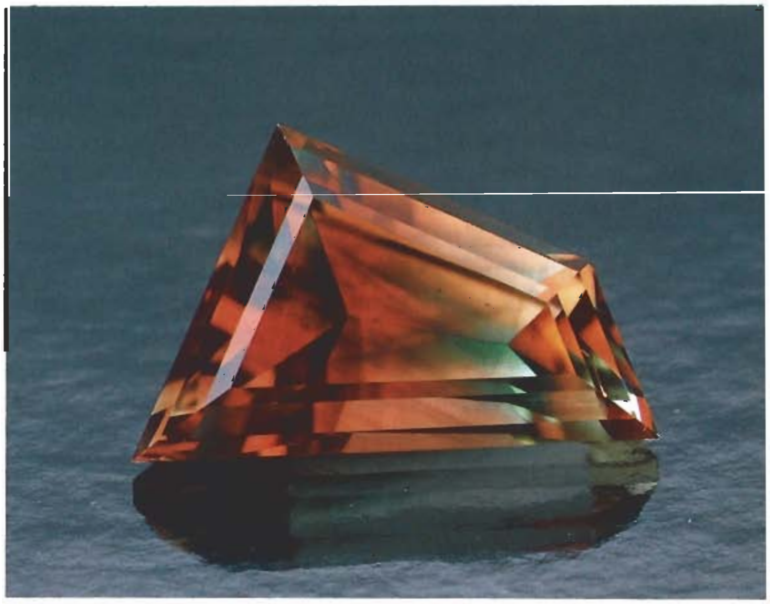


Figure 15. Green is the rarest color variety of Oregon sunstone. This 1.78-ct sunstone is from the Ponderosa mine. Photo © Tino Hammid.

Color in Oregon sunstone is little affected by change in light intensity; these sunstones charac-

Figure 16. The Ponderosa mine also produced this exceptional 1.84-ct bicolored sunstone. Photo © Tino Hammid.



teristically stay "bright" in low or indirect light, whereas many colored gems "die" in low-light conditions. Those stones that have a very strong or saturated green direction (see "Pleochroism" below) are often too dark and, when faceted, become translucent to opaque. This is because higher concentrations of aventurescence-causing inclusions are commonly associated with these strongly pleochroic stones, which accounts for the rarity of fine, brilliant green sunstones. Conversely, saturated red stones seldom exhibit such density of copper inclusions.

Hofmeister and Rossman (1985) reported a specific sequence for color zonation in the Plush material in which green always encircles red and the color boundaries between red and green tend to be sharp. The Ponderosa crystals exhibit a less regular pattern of color sequence and zonation. The exception is that, whatever the color sequence, color zones are always bounded by transparent, colorless zones that extend to the crystal surface.

Although the physical evidence shows extreme variation in color, long-count microprobe study has shown little difference in bulk chemistry from one color variety to the next (table 1). X-ray fluorescence analysis did show significant differences in copper content among nonaventurescent colorless (9 ppm), deeply colored nonpleochroic red (114 ppm), and pleochroic green (84 ppm) crystals (table 2), but any conclusions as to the causes of color based on observed variations in chemistry from colorless through red and green are at this juncture speculative.

Hofmeister and Rossman (1985) suggested that the color in the Plush labradorite is a result of intervalence charge transfer (IVCT) involving copper; trace-element chemistry, as determined using X-ray fluorescence analysis, seems to support this theory. If color is the result of either intervalence charge transfer or the interference effects of intra-lattice colloidal copper, then it will be impossible to isolate a sample free of copper influence, as there would be a smooth linear trend of copper from atomic-level colloids through the megascopically visible platelets. As Nassau (1983) points out, however, ionic concentrations in the range of 0.01 to 0.09 wt.% have been shown to cause intense color in minerals by IVCT. He also suggests that the lower concentration limits that will induce color are unknown. Additional support comes from papers on color in glass caused by colloidal metals (Hopkins and Brown, 1991; Stookey et al., 1978).

Pleochroism. Perhaps the single most striking feature of the Ponderosa sunstone is the strong pleochroism seen in some of the red and green material. Because labradorite belongs to the triclinic crystal system, it is biaxial and can show three directions of pleochroism. Yet labradorites, and feldspars in general, are not normally pleochroic.

Some uniformly red crystals do not show green in any orientation; however, all green crystals have at least one red direction. There are also occurrences of two red directions and a single green direction. Unlike other pleochroic biaxial minerals, whether the third direction is red or green it exhibits the same tone of color as the corresponding direction. Figure 17 shows a generalized relationship between crystal form and pleochroism.

The Ponderosa pleochroic material at times exhibits a strong correlation between twin-plane boundaries and color zonation, with green or red localized within a twin plane. Crystals are commonly observed that have color zonation with the appearance of intertwined fingers, showing both green and red when viewed perpendicular to the twin planes.

The pleochroic appearance depends on the relationship of exhibited color to twin planes. In labradorite, the principal twin planes (i.e., of the albite twins) are parallel to the {010} crystal form. When phenocrysts that exhibit pleochroism are viewed with plane polarized light vibrating perpendicular to {010}, they exhibit a red body color. Conversely, when viewed with plane polarized light parallel to {010}, they exhibit a green body color. The exact relationship between color and crystallographic axis is the subject of ongoing research.

Refractive Indices and Birefringence. Using a Gem Duplex II refractometer and a sodium vapor (589 nm) light source, refractive indices were obtained for 20 typical, randomly oriented, twinned, faceted samples (see table 3). These refractive indices are close to those reported for labradorite in general ($\alpha = 1.560$, $\beta = 1.564$, $\gamma = 1.568$) and correlate well with those of An_{70} specifically (i.e., around 1.569).

In addition, a detailed optical study was undertaken to determine the precise refractive indices and optical orientation of a clear, colorless Ponderosa mine labradorite crystal, using techniques described by Emmons (1928), Bloss (1981), and Gunter et al. (1989) that allow refractive indices to be calculated to approximately ±0.0002. Calibrated liquids were used with a research-grade Leitz polarizing

TABLE 2. Results of XRF chemical analyses[a] of four Ponderosa mine sunstone labradorites.

Element	Sample number[b] 1	2	3	4
Normalized results (wt.%)				
SiO_2	51.11	51.83	50.93	51.03
Al_2O_3	31.01	30.51	31.20	31.13
FeO	0.31	0.32	0.29	0.29
CaO	14.09	13.43	14.23	14.12
Na_2O	3.36	3.74	3.24	3.31
K_2O	0.05	0.11	0.05	0.05
TiO_2	0.047	0.043	0.045	0.044
P_2O_5	0.007	0.009	0.008	0.008
MnO	0.001	0.010	0.011	0.010
Trace elements (ppm)				
Ni	5	6	7	6
Cr	1	nd	nd	nd
Ba	nd	17	nd	nd
Rb	2	3	2	3
Sr	446	614	444	454
Zr	26	32	27	26
Nb	4.7	5.3	6.2	5.9
Ga	11	13	10	12
Cu	9	114	84	110
Zn	3	4	4	1
Pb	2	2	1	1
Ce	1	10	7	nd
Th	nd	2	2	1

[a] *Analyses were performed on a Rigaku 3370 XRF spectrometer using a fused sample-lithium tetraborate ($Li_2B_4O_7$) glass disc and Rhodium target at 50Kv, 50ma, and full vacuum. Data were corrected for matrix effects and line interferences. nd = not detected. Mg, Sc, V, Y, and La were also tested for but not detected at the trace level in any of the samples.*

[b] *Sample 1 was transparent and colorless; sample 2 was intense red along all three optical directions; sample 3 was pleochroic with green body color along one direction and red body color along two directions; sample 4 was pleochroic with green body color along two directions and red body color along one direction.*

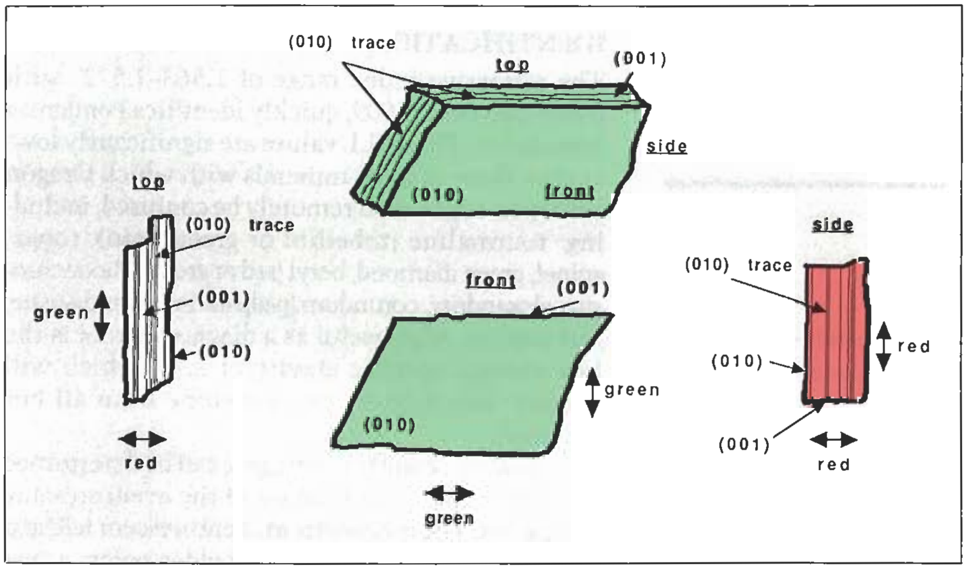


Figure 17. This stylized crystal drawing shows the relationship of pleochroism to crystal form in the Ponderosa sunstones.

TABLE 3. Gemological characteristics of Ponderosa mine sunstone labradorites.

Property (No. samples)	Observations
Color	Moderate to heavily saturated red, pink, orange, and green. Because of pleochroism, some stones exhibit purples and deep plums when cut at 45° to twin planes.
Clarity	All stones exhibit characteristic inclusions of copper lamellae that cause aventurescence. Other types of inclusions are very rare, and include spinel.
Refractive indices	
Single-crystal spindle stage (1)	α = 1.5637(2), β = 1.5681(1), γ = 1.5728(2)
Gem refractometer (20)	1.563-1.572
Birefringence	
Single-crystal spindle stage (1)	0.0091
Gem refractometer (20)	0.009
Optic sign	Biaxial (+)
Twinning	Common albite twinning is often visible at low magnification (<10 ×) under polarized light. Twin planes are usually 1-5 mm thick. Carlsbad and pericline twinning may also be present, but are visible only in thin section.
Cleavage	{001} perfect, {010} good, {100} parting. Cleavage and parting have no effect on cutting or setting.
Specific gravity	
6 fac.	2.68-2.71
6 cab.	2.67-2.72
Pleochroism	Very strong when present. Always present in stones that exhibit green body color; green observed parallel to (010) and red perpendicular to (010).
U.V. luminescence (57, all colors)	Inert to both long- and short-wave U.V.

microscope fitted with a Supper spindle stage and an X-ray goniometer head, as well as an infinitely variable visible light spectrum monochromator and a temperature-variable liquid immersion cell. Using the extinction data, we determined the 2V to be 83.4°(±0.1). Refractive indices of α, β, γ were determined to be 1.5637(2), 1.5681(1), 1.5728(2), respectively. Birefringence was calculated to be $\Delta = 0.0091$.

Specific Gravity. The specific-gravity values for six faceted stones (0.50–2.5 ct) and six cabochons (1.45–4.60 ct) were determined using standard hydrostatic methods. The measured values correspond well with values reported in the literature for labradorite in general (Hurlbut and Klein, 1985). Although the copper inclusions had no obvious effect on specific gravity, their presence may account for the fairly broad range of specific gravities, 2.67–2.72.

Reaction to Ultraviolet Radiation. Twenty-five faceted, eight cabochon, and 57 rough samples were exposed to long-wave (366 nm) and short-wave (254 nm) ultraviolet radiation. All pieces examined were inert to U.V. radiation.

Inclusions. The copper platelets are reflective, a distinct orangy yellow, and appear as rounded ovals in plane view (again, see figure 12); they are nearly undetectable in cross section, average 500 nm across, and rarely exceed 100 μm in longest surface dimension.

Other inclusions in Ponderosa mine sunstone are rare. Dendritic manganese staining has been occasionally noted on partially detached cleavage surfaces, but such stains are not likely to be encountered by the trade as they are usually removed when the rough is prepared for cutting.

A few small (0.1 to 0.5 mm), gray to black, opaque mineral grains with submetallic luster were also observed. One of these grains was removed from a crystal and its bulk chemistry analyzed on an SEM with EDX. It was identified as spinel.

IDENTIFICATION

The refractive index range of 1.563–1.572, with birefringence of 0.009, quickly identifies Ponderosa labradorite. These R.I. values are significantly lower than those of most minerals with which Oregon sunstone might even remotely be confused, including: tourmaline (rubellite or green), pink topaz, spinel, green diamond, beryl (red or green), rhodochrosite, alexandrite, corundum (padparadscha), andalusite, and cuprite. Also useful as a diagnostic tool is the low average specific gravity of 2.71, which will quickly differentiate this sunstone from all but red beryl.

Locality origin (i.e., Oregon) can be determined visually by 10× examination of the aventurescing inclusions. The inclusions in aventurescent feldspar from India have a distinctly redder color, a less reflective dull metallic luster, an angular or euhedral crystal habit, and are an order of magnitude larger than those from Oregon. On 10× examination, even the facet-grade material from Oregon will show some copper platelets. In many faceted stones, copper platelets are visible to the unaided eye (figures 6 and 7).

The distinct red-to-green pleochroism, when present, can also be used to identify the locality origin of Oregon sunstone. No other gem mineral, including labradorite from other localities, exhibits this same distinct red-to-green pleochroism. The pleochroism of andalusite, while strong, is yellow, olive, and red-brown to dark red. Alexandrite has very weak reddish yellow to light green pleochroism. The strong red-to-green color change in alexandrite occurs only with change in wavelength of light, and it is not a specific function of crystallographic orientation. Oregon sunstone exhibits no color change related to light wavelength.

CONCLUSIONS

The Ponderosa mine in northwestern Harney County, Oregon, is now the world's premier location for both facet- and cabochon-quality sunstone labradorite feldspar. Current known ore reserves at the Ponderosa mine suggest at least 20 years of production at the one-million-carats-per-year level. By comparison, current estimates suggest that the Plush area is capable of producing at the 250,000- carats-per-year level. No other known deposit produces or historically exhibits as wide a range of colors, as well as pleochorism and aventurescence in three directions.

The present study concludes that the aventurescence is a result of the precipitation of copper platelets driven by decreasing pressure and temperature during formation. While no cause of color was positively identified, it is suggested that the intense color in these gems may be the result of intervalence charge transfer between unknown metal ions, possibly involving copper. Specifics of both the color mechanism and the origins of the aventurine effect are the topics of additional study currently in progress.

The key identifying characteristics of Ponderosa mine sunstone include refractive index and specific gravity. Finally, both the copper inclusions and the presence of strong red-to-green pleochroism provide proof that the locality of origin is Oregon.

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NOTES AND NEW TECHNIQUES

CURVES AND OPTICS IN NONTRADITIONAL GEMSTONE CUTTING

By Arthur Lee Anderson

A series of cuts, designed by the author, exhibit extraordinary optical effects that result from a combination of curved surfaces and plane facets placed to take advantage of internal reflection. Examples are provided that illustrate the cutting techniques for two of these "open-table" cuts.

In recent years, a renaissance of sorts has been taking place in gem cutting. Increasingly, cutters (in particular, custom cutters and gemstone designers) have broken with the conventions of traditional faceted cuts and have incorporated new shapes and techniques in their approaches to stones. The results have been as varied as the cutters themselves.

Many of these newer cuts indicate a trend toward carving and sculpting, rather than flat faceting or cutting en cabochon (see, e.g., Koivula and Kammerling, 1988 a and b). While the results are often beautiful and unusual, at times they appear to sacrifice the use of internal optics in favor of a more unusual external shape. This article illustrates some ways in which the cutter can still use internal optics as the central characteristic of a cut while executing unconventional treatment of a stone wherein curved surfaces are produced freehand on a flat lap.

ABOUT THE AUTHOR

Mr. Anderson is a lapidary and gemologist whose business, Speira Gems (P.O. Box 849, Ashland, Oregon 97520), deals in a variety of gemstone-related activities, from custom cutting and stone design to gem identification and sales.

Acknowledgments: The author wishes to thank Mr. Robert Jaffe of Ashland, Oregon, who provided most of the excellent photographs that accompany this article. Additional thanks go to Ms. Ione Rodenick, who indirectly inspired the "halo" cut, and to Ms. Martha Wilhelm, who likewise inspired much of my work. Goldsmithing for the amethyst-and-opal pendant was provided by Mr. Ron Hansen of Gold & Gems Jewelry, Ashland, Oregon.

Gems & Gemology, *Vol. 27, No. 4, pp. 234–239*

DESCRIPTION OF SAMPLES

Two gems were selected to illustrate the principles proposed here. The first is a pyramid-shaped 8.98-ct golden beryl, finished in what I call a "halo cut" (figure 1). In this cut, the crown has been virtually eliminated and the table "spread" in order to emphasize the internal optical effects and draw the observer's eye past the surface shape of the gem and into the interior. The name of this cut is based on the circle, or halo, of light that moves around the interior of the stone as it is turned.

The second example is a 12.90-ct hexagon-shaped yellow labradorite with an "iris cut" (figure 2), so named because it exhibits a petal effect similar to that of the flower. As the stone is moved,

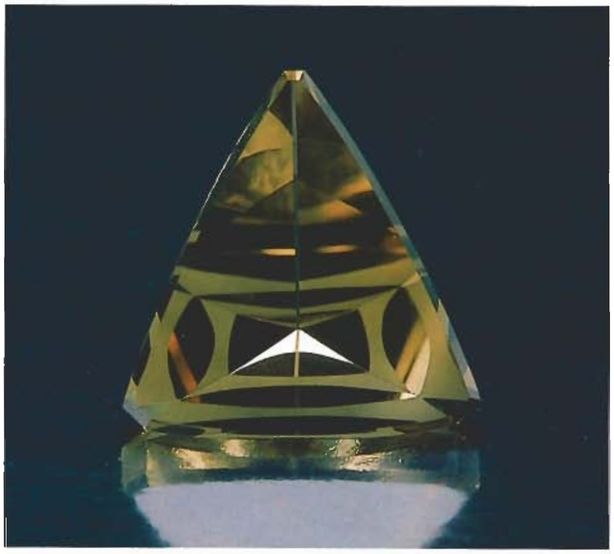

Figure 1. The halo cut of this 8.98-ct golden beryl eliminates the crown and "spreads" the table to draw the observer's eye into the interior of the stone. Photo © Robert Jaffe.

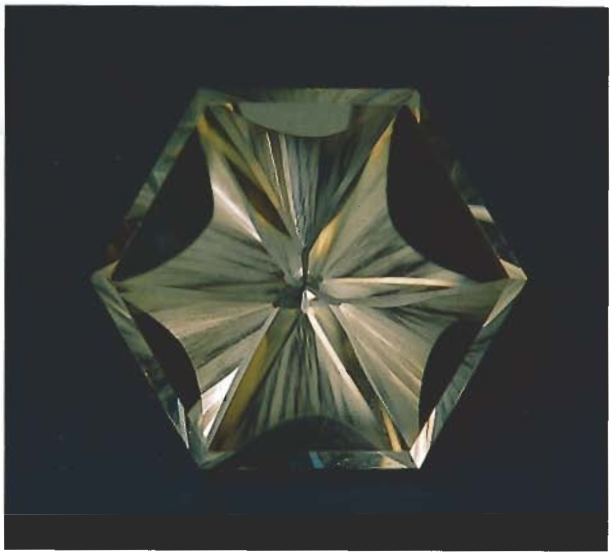

Figure 2. The "petals" of this iris cut appear to approach or recede from the table as the stone, here a 12.90-ct labradorite, is moved. Photo © Robert Jaffe.

the "petals" appear to approach or recede from the table, sometimes seeming as much as a half-inch from the table surface, although the stone is only 10 mm deep. Again, the crown is essentially eliminated, leaving an open table, to place the focus on internal optics.

GENERAL CUTTING CONSIDERATIONS

Rough. These cuts require that rough material be internally flawless, since the open tables expose virtually all of the interior of the finished stone. Moreover, the use of optical reflection to create the internal effects will "multiply" any small inclusion.

A variety of materials have proved to be suitable for these cuts, including quartz, topaz, spinel, and corundum, as well as the beryl and labradorite illustrated. However, the crisp definition provided by singly refractive materials such as spinels seems to be particularly effective (figure 3).

Medium to light colors produce the best results. Larger sizes also seem to be optimum, although I have successfully produced the pyramidal halo cut in stones as small as 6 × 5 mm that were still interesting and effective.

Figure 3. These cuts are particularly effective on singly refractive gem materials such as spinel. This 9.75-ct halo-cut synthetic spinel demonstrates the "holographic" quality whereby the interior design appears to move beyond the periphery of the girdle. Photo © Robert Jaffe.

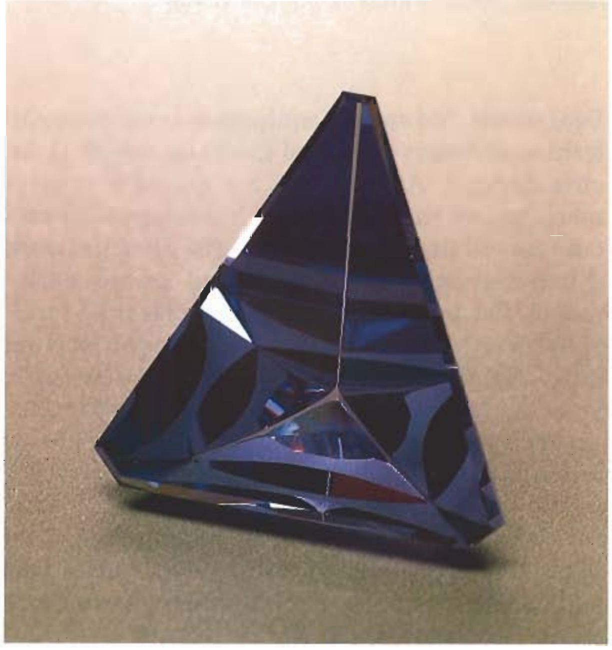

Figure 4. Although standard equipment is used for these cuts, considerable "play" is needed in the faceting head to allow for small adjustments in facet placement. Here, the author is actually touching the lap with his fingertips to maintain maximum control while cutting a freehand curve. Photo by Martha Wilhelm.

Equipment. No special equipment is necessary to fashion the convex curved facets on which these cuts depend. Although there are now special machines on the market that are designed to execute curved surfaces (Homer, 1990), all of the work illustrated here was executed on an old, early-model, flat-lap unit with a generic faceting head. However, there is excessive "play" in the faceting head, which permits small adjustments to be made in facet placement with the exertion of slight finger pressure (figure 4). My equipment also includes a heavy steel base for stability, with a 0 to 3000 rpm motor and rheostat, and a variety of laps (metal bonded, glass, copper rechargeables) and grits (100 to 3000). Polishing is performed with Lucite laps and cerium oxide, tin-lead, and Linde A, or a Crystolite "Last Lap" for 50,000-grit diamond.

Preforming. For the cuts described in this article, no special consideration need be taken in preforming except to leave a slight bulge wherever you plan to produce a curved surface later. The amount of bulge left is comparable to that allowed in cutting the pavilion of a step cut, where the finished facets bow out (Sinkankas, 1962).

Dopping. Typical cold dopping is recommended for all materials except corundum. Cyano-acrylic glue is used to hold the stone in the wax mold; the stone can be removed after cutting by soaking in acetone (except where oiling is suspected) or by gently scraping the glue with a razor blade. (For more on cold dopping, see Wycoff, 1985.)

HALO CUT

Anyone who has successfully rounded a girdle freehand has the skill necessary to cut a curved facet. Generally, the table is cut first, beginning with a 45° adapter and a 260-grit lap, followed by 600- and 1200-grit laps. The table is finished with whatever lap and polishing compounds are suitable to achieve an optimally reflective finish on the gem material being cut.

After the table has been cut and polished, the girdle is cut. Indexing will depend on what type of gear is used, but it should be set slightly off from an equilateral triangle to achieve the pyramid shape shown here.

Then, while the stone is still dopped from the pavilion, a set of small girdle step facets (generally 0.5 to 1 mm or more, depending on the final dimensions of the stone) are cut on the crown. For larger stones, sometimes two sets are cut. The purpose of these facets is mainly to provide a surface for a bezel or prongs to grip when the stone is set in jewelry.

At this point, I generally crop the corners of the triangle to protect against chipping during setting, but they may be left sharp. Both the crown girdle facets and the corner facets are usually cut straight with a 1200-grit lap. Then, once the crown is completed, the stone is transferred to a dop centered on the triangular table.

Two broad mirror facets are cut on the pavilion, at an angle of 50° to the girdle plane (figure 5). These two surfaces will determine the sharpness of the reflected design, so they must be cut and polished as cleanly as possible. The 50° angle is sufficiently larger than the critical angle of most gem materials that the internal design does not wash

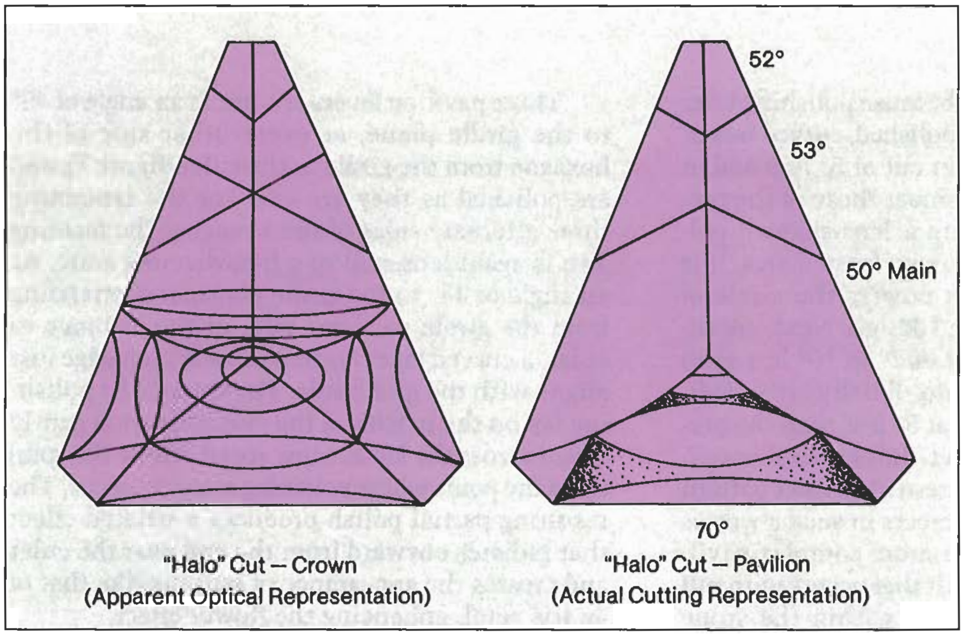

Figure 5. The appearance of a halo-cut gemstone as seen through its crown (left) is quite different from what might be expected from the pattern of faceting on its pavilion (right)—a result of placing the pavilion facets to take advantage of internal reflection.

out as the angle of observation changes. Two additional sets of facets are then cut, at 53° and 52°, toward the apex of the pyramid (again, see figure 5). These facets only provide aesthetic activity towards the top of the stone and are not integral to the optical phenomenon of the design, as are the 50° main facets. The deep pavilion that results from these steep pavilion angles does require some creativity in designing settings. On the other hand, these cuts are particularly striking in closed-back mountings (figure 6).

It takes some practice to form the combination of alternating flat and curved facets that results in the desired design and optical pattern. Beginning at the base index spot and working from the girdle toward the culet, a flat facet is first cut and polished at approximately 70° to the girdle plane (again, see figure 5). At approximately 5° less, the next facet is cut as an arc. This is done by locking the faceting arm in a freewheeling position so that it rotates freely. Using a worn 600- or a new 1200-grit lap, gently sweep the stone across the lap in tight, economical movements, constantly checking the evolution of the curve until a graceful arc is achieved. The arc is left unpolished to provide sharp definition and contrast with the adjacent flat facets. The frosted surface also acts as a "light sponge" that cuts down internal brilliance and optimizes the desired optical activity.

The next facet, like the first, is flat and is cut at an angle of 3°-5° less than that of the previous surface. Again, it is polished; all flat facets should

Figure 6. The optical effects of these cuts are particularly good when stones are placed in a closed-back setting, as can be seen in the 13.50-ct halo-cut amethyst in this 14k gold pendant, also set with opal. Photo © Robert Jaffe.

be polished as they are cut, because polishing later might alter the adjacent, unpolished, curved facets. Next, a curved facet is again cut at 5° less and in such a way that its corners meet those of the previous curved facet, forming a lens-shaped, polished flat facet between the two frosted arcs. It is this lens-shaped facet that creates the circle of light, or halo, in the finished design. Next, another flat, polished facet is cut at 7° to 10° less than the previous, unpolished arc. Finally, two additional polished arcs are cut at 5° less than the previous cut to form the culet. Internal reflection transfers the image of the alternating facet pattern to the two large, flat, main facets in such a way as to form the appearance of a more complex pavilion faceting. Unlike the result that occurs with full faceting, however, the image within the stone moves around the pavilion as the viewing angle changes.

IRIS CUT

This hexagonal cut is somewhat easier to execute than the halo cut, although it employs similar principles of curves and reflection. It uses the same basic indexing as for other hexagonal cuts. The table is again left "open" and is cut and polished first, followed by the hexagonal girdle and minor crown girdle facets. The stone is then re-dopped to cut the pavilion sequence.

Three pavilion facets are cut, at an angle of 45° to the girdle plane, at every other side of the hexagon from the girdle to the culet (figure 7), and are polished as they are cut. For the remaining three alternate sides of the hexagon, the faceting arm is again loosened to a freewheeling state. At an angle of 44° to the girdle plane, and extending from the girdle to about 90% of the distance to culet, a curved facet is cut so that its top edge just aligns with the girdle side. Then, with the polishing lap on the machine, the curved facet is gently rolled across the lap at a low speed (about 100 rpm) up to the point where polishing starts to occur. The resulting partial polish produces a striated effect that radiates outward from the end near the culet and creates the appearance of striping like that of an iris petal, enhancing the flower effect.

This cutting sequence establishes a striated, curved surface opposite each flat, planar pavilion facet. Reflection of the curved surfaces by the plane surfaces causes the reflected image, as viewed from the crown, to appear to recede from the viewer. This receding effect is juxtaposed on the positive, nonreflecting, striated surface, the contrast adding to the apparent depth in the stone.

CONCLUSION

No specific mathematical approach was adopted to determine the angles used in the cuts described

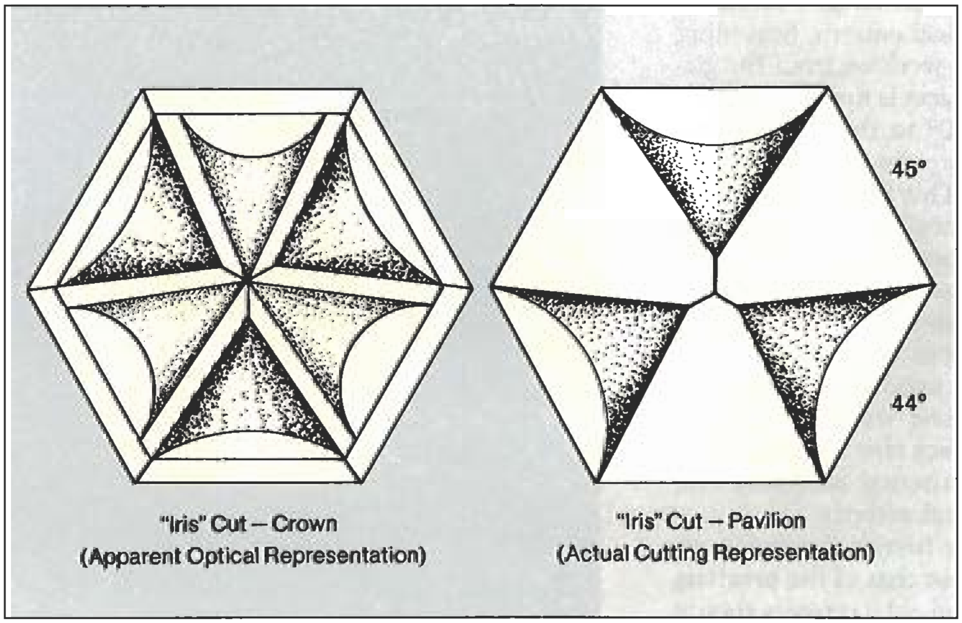

Figure 7. The crown view of an iris-cut stone (left) results from internal reflection of the pavilion facets (right), three of which are left partially polished to achieve the striation that contributes the iris-petal appearance.

above. The final designs are accomplished generally by making adjustments as the stone evolves. By cutting and polishing the table first, "en route" checking can be done, enabling the cutter to make minor angle adjustments by eye, as needed. Another example of some of the possibilities of "en route" designing is exhibited by the 17.5-ct "leaf-cut" citrine shown in figure 8. The natural skin of the rough citrine crystal was retained in the design of the stone, and is accentuated by select reflective planes on the pavilion. Although optical reflection is not intrinsic to this design, this open-table cut demonstrates again the concept of drawing the observer's attention past the surface and into the stone.

In this type of cutting, flexibility is central to creation and design. Experience and practice are also critical. In addition, it is important to record every step in the process to ensure that you can reproduce or make corrections to the design later.

As with all lapidary work, the hand and the eye are the paramount tools, but recent developments have also revealed the importance of the cutter's imagination. Experimentation will lead to the creation of even more variety and, as the "kinks" are worked out, the future should see a diversity of cutting styles and techniques that incorporate a balance of form and optics that both pique the interest and satisfy the aesthetics of the beholder.

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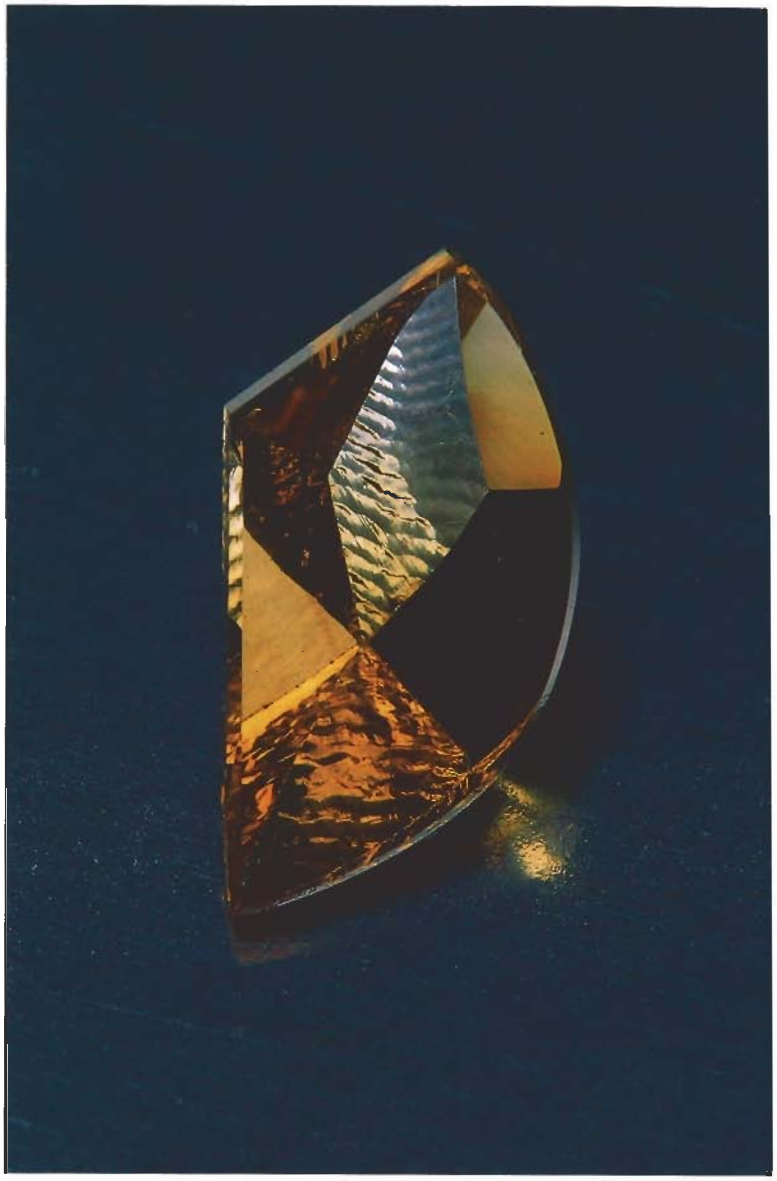

Figure 8. This 17.5-ct "leaf-cut" citrine demonstrates another example of how to optimize the interior of a stone by means of the open-table concept. Photo © Robert Jaffe.

AN EXAMINATION OF NONTRANSPARENT "CZ" FROM RUSSIA

By Robert C. Kammerling, John I. Koivula, Robert E. Kane,
Emmanuel Fritsch, Sam Muhlmeister, and Shane F. McClure

White, pink, and black nontransparent synthetic "cubic zirconia" is currently being manufactured in Russia and marketed primarily in cabochon and bead form. These unusual materials are potentially useful as substitutes for such gem materials as pearl, dyed black chalcedony ("onyx"), and even black diamond. The authors provide a detailed description of these new products, including the chemistry and probable manufacturing techniques. These products can be readily identified by standard gemological tests.

Synthetic cubic zirconia (CZ) is best known as a transparent, essentially colorless diamond simulant. Few would argue that, to date, it is the most effective imitator of that important gem. Annual production now exceeds one billion carats (Nassau, 1990). In 1989 alone, Thailand exported 13,256 kg (66,280,000 ct) of fashioned CZ ("Thais cut more CZ," 1990).

ABOUT THE AUTHORS

Mr. Kammerling is director of technical development, Mr. Koivula is chief gemologist, Dr. Fritsch is research scientist, and Mr. Muhlmeister is a research technician in the Research Department, at the Gemological Institute of America, Santa Monica, California. Mr. Kane is manager of identification and Mr. McClure is senior gemologist in the GIA Gem Trade Laboratory, Inc., Santa Monica.

Acknowledgments: The authors thank Mr. Kyle Kisseberth, of Kyle Christianson Ltd., and Mr. Joseph Wenckus, of Ceres Corp., for providing valuable information. Mr. Lennon Brown, of the GIA Jewelry Manufacturing Arts Department, conducted the heat-treatment experiments.

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Over the past several years, CZ has also become available in a wide variety of colors, including some that make effective imitations of fancy-color diamonds (see, e.g., Nassau, 1981; Crowningshield, 1985; Hargett, 1990) and others that imitate various other gems (see, e.g., Nassau, 1981; Read, 1981, 1989; Fryer et al., 1983).

Until recently, virtually all CZ has been essentially transparent. In the Fall of 1991, however, we learned that nontransparent "cubic zirconia" was being manufactured in Russia and marketed in the United States by the firm of Kyle Christianson Ltd., Sylvania, Ohio. One type, produced in both white and pink, is marketed as "Pearl CZ" (Weldon, 1991) because of its resemblance to the organic gem material. In subsequent discussions with employees of the Christianson firm, we learned that they also sell a black CZ.

According to Kyle Kisseberth of the Christianson firm (pers. comm., 1991), all three types are produced in Novosibirsk, Russia. The Christianson firm first marketed them in early to mid-1991. Both rough and fashioned (white and pink, primarily cut en cabochon; black, faceted or as beads)

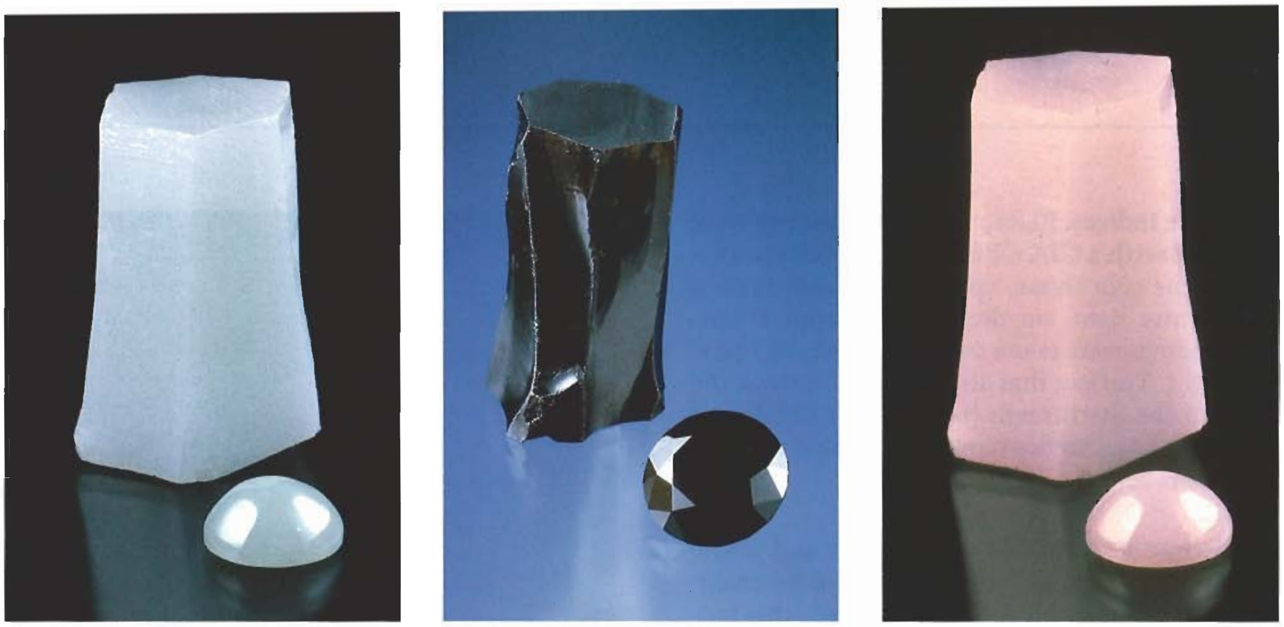


Figure 1. These samples are representative of the material examined in this study (from left to right): white "Pearl CZ" (98.62 ct and 8.03 ct), black CZ (65.09 ct and 6.60 ct), and pink "Pearl CZ" (141.85 ct and 7.14 ct). Photos by Shane F. McClure.

materials are sold, with the fashioning done in Bangkok. As of late November 1991, over 1,000 kg each of the white and pink materials, and almost 1,000 kg of the black, had been sold.

In terms of the materials' jewelry use, Mr. Kisseberth indicated that the white and pink cabochons have found their most obvious application as a reasonably priced simulant for Mabe pearls. The black material has been marketed to date as a substitute for (dyed) "black onyx" (chalcedony), having the advantage of greater scratch resistance. To establish the properties of these three materials and determine the cause of their unusual appearance, we examined several samples of each and submitted them to a number of testing procedures. The results are reported below.

SAMPLES STUDIED

The authors obtained the following samples from the Christianson firm: five cabochons (4.39-8.03 ct) and one "crystal" (98.62 ct) of the white; five cabochons (3.75-7.83 ct) and one "crystal" of the pink; and three faceted (0.57-6.60 ct) and three "crystals" (65.09-87.47 ct) of the black. All of the cabochons had slightly convex bases. Representative samples of these materials are shown in figure 1.

PROPERTIES

The properties determined on these samples are summarized in table 1 and discussed below.

Visual Appearance. The white "Pearl CZ" has a uniform, milky white body color while the pink "Pearl CZ" has a uniform, medium pink body color. When examined with moderately intense direct transmitted lighting, all the cabochons appeared translucent. With more intense lighting, however, all the cabochons showed subtle variations in translucency with a somewhat banded, striped, or striated distribution. Where this was most noticeable, as in two of the pink cabochons (figure 2), the appearance was somewhat reminiscent of the striped effect noted when bead-nucleated cultured pearls are examined in intense transmitted light, a technique known as "candling" (see, e.g., Webster, 1983, p. 541; Liddicoat, 1989, p. 123). Nassau (1980) described and illustrated a similar effect that occurs occasionally in transparent colorless CZ.

In reflected light, the black material appears to have a uniform coloration. When placed over the end of a fiber-optic light pipe, the larger samples remain essentially opaque, transmitting no light. The smaller pieces, however, appear semitranslucent and exhibit a dark brownish red transmission reminiscent of the body color of almandite garnet (figure 3); a thin (approximately 1.75 mm) slice of one of the larger rough specimens exhibited the same transmission color.

The luster of all the polished samples was notably high. The luster of the black material is best described as adamantine, as the faceted samples resemble some black diamonds. Using the GIA cultured pearl grading system (GIA, 1984), as the white and pink materials are marketed as pearl simulants, the luster of the "Pearl CZ" would be classified as very high.

Refractive Indices. Refractive index readings were measured with a GIA GEM Duplex II refractometer. On the cabochons, spot readings were taken using white light; on the faceted samples, flat-facet readings were taken using near-sodium equivalent light. The fact that all readings were over the limits of the instrument (i.e., above 1.81) is consistent with the values reported for cubic zirconia (see e.g., Liddicoat, 1989).

Polariscope Reaction. Both the pink and white cabochons transmitted enough light to be examined between crossed polars; in all cases this produced an aggregate-type reaction. All the black specimens appeared opaque in the polariscope, so no optic character could be determined for this material.

Ultraviolet Luminescence. The white material was essentially inert to long-wave U.V. radiation. This material fluoresced a very weak light pink to

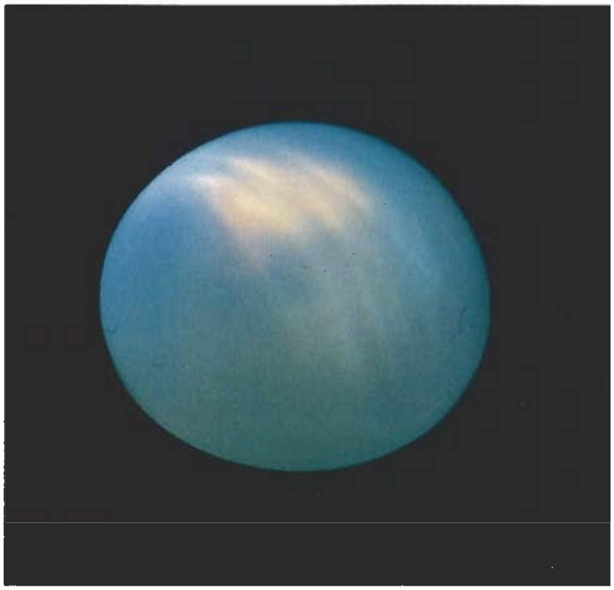


Figure 2. In strong transmitted light, this 7.83-ct pink "Pearl CZ" exhibits a characteristic striped appearance. Photo by Maha Smith.

TABLE 1. Gemological properties of nontransparent white, pink, and black "CZ."

Properties	White	Pink	Black
Visual appearance			
Reflected light	Uniform milky white	Uniform pink	Uniform black
Transmitted light	Somewhat banded, striped, or striated	Somewhat banded, striped, or striated	Dark brownish red transmission color
Diaphaneity	Translucent	Translucent	Semitranslucent to opaque
Polish luster	Very high	Very high	Very high (adamantine)
Refractive index	OTL[a]	OTL[a]	OTL[a]
Polariscope reaction	Aggregate	Aggregate	N/A[b]
Ultraviolet luminescence			
Long-wave	Inert	Strong yellow-green	Inert
Short-wave	Very weak light pink	Weak to moderate chalky light yellow-green	Inert
Absorption spectrum[c]	No detectable features	Fine lines at approx. 440, 449, 541, 543, 546, 644, 646, 650, 653, 655, and 656 nm; wider bands at 486, 515, and 523 nm	No detectable features
Chelsea filter reaction	Yellowish green	Yellowish green	Dark red
Thermal conductivity reaction[d]	—	—	Simulant
Specific gravity[e]	6.11-6.12	6.14-6.16	5.93-5.94

[a] *Over the limits of the conventional refractometer (1.81+).*
[b] *All black specimens appeared opaque in the polariscope.*
[c] *Visible range (400-700 nm), as determined using both prism and diffraction-grating type desk-model spectroscopes.*
[d] *Test not performed on pearl simulants; reaction of black material typical of that observed with other colors of CZ.*
[e] *Determined by hydrostatic weighing method.*

short-wave U.V. There was no phosphorescence to either wavelength.

The pink material fluoresced a strong yellow-green to long-wave U.V. and a weak to moderate chalky light yellow-green to short-wave U.V. Again, there was no phosphorescence. This response resembles the fluorescence reaction of transparent pink CZ (Read, 1981).

The black material was inert to both wavelengths.

Chemistry. All three types of material were analyzed using a Tracor Spectrace 5000 energy dispersive X-ray fluorescence (EDXRF) spectrometer, and all were found to contain zirconium, hafnium, and yttrium. Yttrium is a common stabilizer used in the production of CZ, while hafnium is an impurity associated with zirconium (Bosshart, 1978). The relative proportions of zirconium and yttrium found in the spectra of the "Pearl CZ" differ from those measured for a transparent, colorless, yttrium-stabilized CZ sample run for comparison. Normalizing the peak heights for zirconium in the chemical spectra of the opaque and transparent CZ samples reveals an yttrium peak height for the transparent CZ that is approximately four times greater than that of either the white or pink translucent materials. In other words, the yttrium stabilizer concentration is approximately four times greater in the transparent CZ studied than in the nontransparent material. The pink samples were also found to contain erbium (chemical symbol: Er), a rare-earth element. The chemistry of the black CZ was found to be very similar to that of the transparent, colorless CZ. In some samples (of all colors), we found traces of iron, calcium, and manganese, which are common trace elements in colorless CZ.

Spectroscopy. All samples were examined using GIA GEM desk-model spectroscopes, both prism and diffraction-grating types (the latter with an LCD digital readout). Neither the white nor black materials exhibited any detectable absorption features.

The pink specimens, however, exhibited a strong absorption pattern of the type associated with gem materials that contain rare-earth elements. The most prominent features were fine lines at approximately 440, 449, 541, 543, 546, 644, 646, 650, 653, 655, and 656 nm, with wider bands at 486, 515, and 523 nm. Where lines are tightly spaced (for example, the four between 650 and 656 nm), they may appear as a single, broad line. The spectrum is similar to that noted by the authors in some transparent pink CZ and attributed by Read (1981) to doping with erbium oxide (Er_2O_3); Nassau (1981) also reports erbium (as well as europium and holmium) as a dopant used to produce pink CZ. This is consistent with the results of the chemical analysis described above.

Figure 3. Thin edges and smaller faceted pieces of the black CZ, like this 0.57-ct triangular brilliant, appear brownish red when examined in strong transmitted light. Photo © GIA and Tino Hammid.

The ultraviolet, visible, and near-infrared absorption spectra of the pink and white materials were also measured using a Hitachi U-4001 U.V.-visible spectrophotometer (figure 4). The white material does not show any absorption in the visible range, which is consistent with its color appearance. It does, however, exhibit some very weak, broad absorptions in the near-infrared between 1700 nm (5880 cm^{-1}) and 2500 nm (4350 cm^{-1}).

By contrast, the pink samples show a series of very sharp absorptions in the visible range. The strong absorptions located between 480 and 550 nm result in the pink color. It is interesting to note that these features are accompanied by broader ones at about 900 and 1500 nm in the infrared, as well as the much weaker set of broad absorptions already observed for the white material.

The near-infrared and visible absorption spectra of the pink material arise from the presence of the erbium ion Er^{3+}. Except for the features

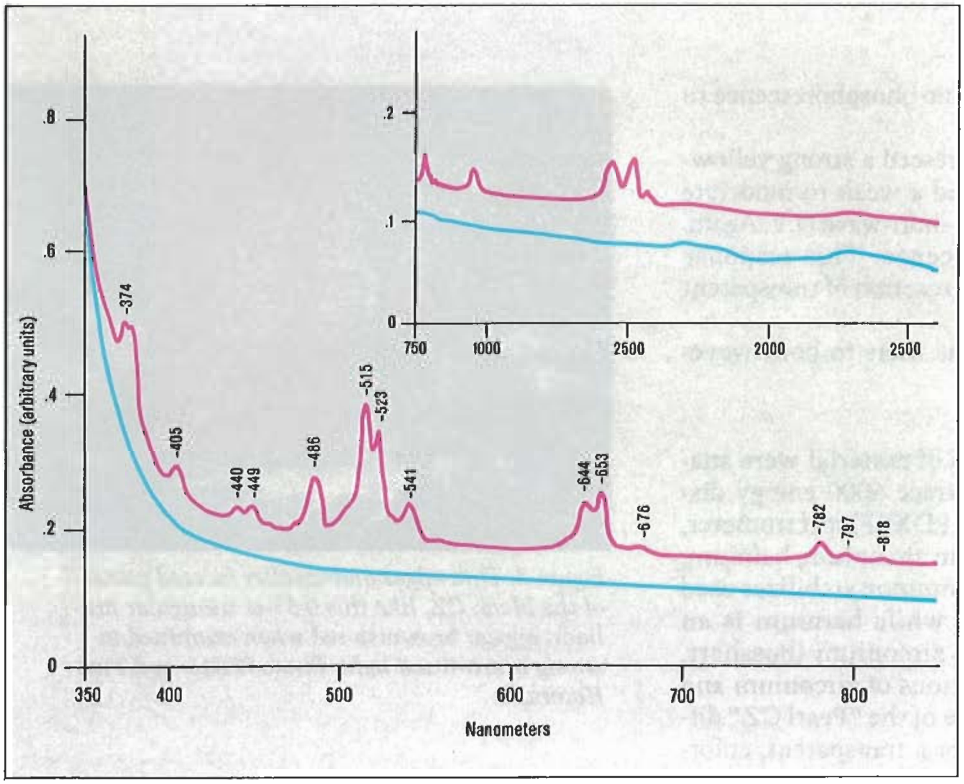


Figure 4. The ultraviolet-visible absorption spectra of white (lower curve) and pink (upper curve) "Pearl CZ" are shown here. The near-infrared absorption spectra of the same samples appear in the box (the axes of the box have the same units of measure as the larger spectra).

between 1700 and 2300 nm, the various groups of sharp absorptions from the ultraviolet to the near-infrared can be attributed to the various energy levels of the Er^{3+} ion observed by Dieke (1968, p. 134) in the $LaCl_3$ structure.

Because the pink material exhibits such a strong luminescence to long-wave U.V. radiation, we also examined the emission spectrum with a desk-model prism spectroscope. This revealed two sharp lines in the green, at approximately 540 and 550 nm, that correspond to the 541-nm absorption (and its very weak 550-nm companion) of the Er^{3+} ion (figure 5). Therefore, the U.V. luminescence is due to this dopant.

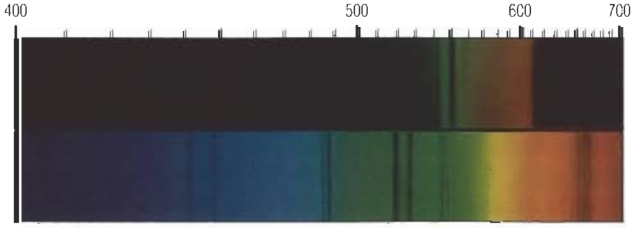
Chelsea Filter Reaction. The white and pink samples were viewed through a Chelsea filter while illuminated in the strong transmitted light provided by the base lighting system of a GIA GEM spectroscope, as were the smaller faceted black specimens and extremely thin edges of the black rough samples. Both white and pink types appeared yellowish green. As for the black samples, all areas that transmitted light appeared dark red.

Thermal Conductivity. Because the black "CZ" could be visually confused with some black diamonds (its over-the-limits R.I. could add to such confusion), it was tested with a thermal conductivity probe. All of the samples revealed a typical "simulant" reaction.

Specific Gravity. S.G. was determined by the hydrostatic method with a Mettler AM100 electronic scale. Three separate determinations were made for each sample so tested. The white material gave values of 6.11-6.12, the pink produced values of 6.14-6.16, and three of the black specimens (the larger ones) gave values of 5.93-5.94.

The values for the white and pink materials are somewhat higher than those generally reported

Figure 5. Comparison of the yellow-green long-wave U.V. fluorescence spectrum (upper) with the optical absorption spectrum of the pink material demonstrates that this luminescence originates mostly from the Er^{3+} ion.



for cubic zirconia (see, e.g., Nassau, 1981; Liddicoat, 1989). However, Read (1981; 1989) points out that both refractive index and specific gravity of CZ can vary with the amount and nature of stabilizer used. The values for the black material are within the range described in the literature for transparent, colorless CZ (e.g., Nassau, 1980; Liddicoat, 1989).

Magnification. Observation of the samples with a standard binocular microscope revealed no additional distinctive features. In surface-reflected light, the "Pearl CZ" showed an essentially smooth surface (in contrast to the contoured platelet structure of pearls).

DISCUSSION

Cubic zirconia is produced commercially by a technique known as skull melting, in which crystals are grown at high temperatures in a self-contained melt or cold crucible of powdered zirconium oxide (for a more complete description of the technique, see Nassau, 1980).

Of particular relevance to this discussion is the fact that a stabilizer—normally yttrium oxide or calcium oxide—must be used if the end result is to be a stable product crystallized in the isometric (cubic) crystal system. When yttrium oxide (Y_2O_3) is used, the amount might typically be on the order of 15 wt.%, although a cubic product can be produced with up to about 65 wt.% (J. Wenckus, pers. comm., 1991). One of the early patents filed is for cubic zirconia stabilized with 10 to 30 mol.% (16-44 wt.%) yttrium oxide (Nassau, 1980).

The amount of stabilizer is of particular interest here, as it appears from the following that the reduced transparency in both the white and pink materials results from the intentional use of insufficient stabilizer. According to Mr. Joseph Wenckus of Ceres Corp., a major U.S. manufacturer of CZ, inadequate amounts of stabilizer (for example, 5-6 wt.% yttrium) result in a material that consists of a multitude of tetragonal zirconia needles (ZrO_2) contained within a cubic zirconia matrix. Under very high magnification, Ingel (1982) observed a "tweed-like" structure in a thin section of material containing 5 wt.% yttrium oxide. The reduced transparency is the result of light scattering from these tetragonal needles. Mr. Wenckus also volunteered that, with respect to nomenclature, these products are not cubic zirconia but rather partially stabilized zirconia (PSZ).

Ceres Corp., under contract with the Naval Research Laboratory in Washington, DC, has grown a wide variety of PSZ crystals over the past 10 years, some of which have been marketed in small quantities to the gem trade (J. Wenckus, pers. comm., 1991). The authors examined a 144.66-ct white specimen, produced this past year, that was virtually identical in appearance to the white material produced in the Soviet Union. EDXRF analysis by the authors confirmed that it had yttrium and zirconium concentrations similar to those of the white "Pearl CZ."

R. P. Ingel (1982) provides further quantitative data relating yttrium content to the crystal transparency of CZ and related materials. At 3 and 4 wt.% Y_2O_3, the crystals are white and essentially opaque; at 5 wt.%, they are semitranslucent; and at 12-20 wt.%, they are transparent and colorless. This is consistent with results of the semi-quantitative chemical analyses obtained for this study.

The authors believe that the light scattering described herein alone accounts for the body color of the white material, as this material did not appear to contain a color-producing dopant. Furthermore, the striped appearance seen when the white and pink "Pearl CZ" is illuminated in strong transmitted light can be accounted for by the inhomogeneous nature of these materials.

The fact that the black samples showed no major chemical difference from the colorless reference samples indicates that their color is not due to the presence of trace elements.

Mr. Wenckus has also volunteered an explanation for the appearance of the black CZ, which Ceres Corp. has also grown in small quantities for customers in the gem trade. Such material can be produced by growing CZ under neutral and/or reducing conditions. (Alternatively, transparent CZ crystals can be "blackened" by post-growth annealing under the same atmospheric conditions [i.e., neutral or reducing] at temperatures above 1400°C). In either case, the resulting product contains color centers that absorb so much light as to cause the black color. Heating such material in an oxidizing atmosphere eliminates color centers, resulting in transparent, colorless CZ. In fact, Mr. Wenckus noted, jewelry repair operations, such as the retipping of prongs with the material still in the mounting, have had the undesired effect of turning the material colorless.

To confirm this report, the authors had a cross-

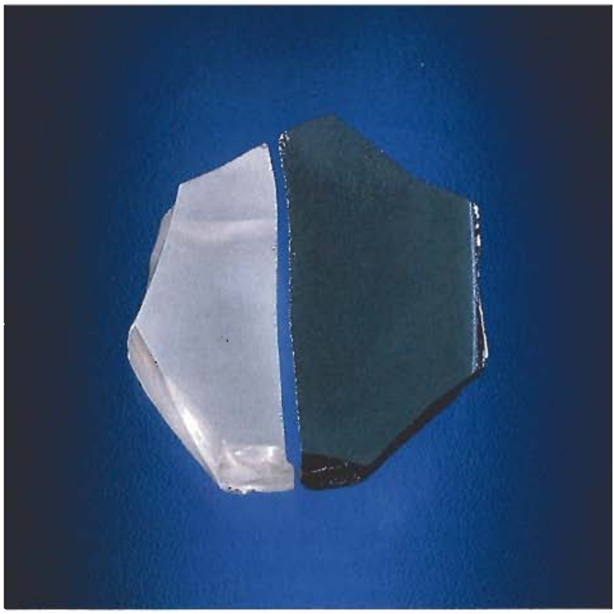


Figure 6. Heating to a red heat with a jeweler's torch caused the 6.02-ct piece of black CZ on the right to become transparent and essentially colorless. The 8.37-ct piece on the left was cut from the same original rough. Photo by Shane F. McClure.

sectional piece sawn from one of the samples of black rough and subsequently had it cut into two pieces. The larger (8.37 ct) piece was retained as a control while the smaller (6.02 ct) piece was heated on a charcoal block to a red heat with a jeweler's torch. Upon cooling, the smaller piece became transparent and essentially colorless (figure 6). A similar heating procedure performed on a 5.20-ct white cabochon and a 7.10-ct pink cabochon produced a temporary color change at high temperature, but both stones reverted to their original appearance on cooling.

CONCLUSION

The white and pink "Pearl CZ" investigated for this report appear to be partially stabilized zirconia (PSZ), which lacks sufficient stabilizer to produce a homogeneous cubic structure. Although the materials exhibit neither overtone nor orient (two components of pearl color), they are attractive and do make relatively effective pearl imitations in some jewelry applications. Their significantly higher density (6+ vs. less than 3 for natural and cultured pearls), over-the-limits R.I.'s, and smooth surface should serve to separate them easily from natural and cultured pearls. Care must be exercised, however, not to mistake their appearance in strong transmitted light for the "candling" effect seen in some bead-nucleated cultured pearls. It is interesting to note that because the reduced transparency of the PSZ is not connected to the colorant used, one may assume that any of the other colors of CZ could be similarly produced in a translucent to opaque form.

With its high luster, the black, partially reduced CZ could make an effective simulant for a number of black gems, including black diamond. A "diamond probe" should serve to separate this material quickly from either natural-color or artificially irradiated black diamonds. In addition, the brownish red transmission color noted in small samples and thin sections of this simulant differs from the light gray or brown to colorless appearance of transparent areas of natural-color black diamonds or the green transmitted color of irradiated "black" diamonds (Kammerling et al., 1990).

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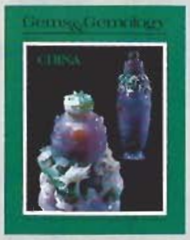

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GEM TRADE LAB NOTES

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A Large CHLORITE Carving

Recently submitted to the West Coast laboratory for identification was the opaque, mottled, yellowish brown to brownish yellow oriental carving illustrated in figure 1. Our client reported that this interesting piece—possibly a scepter—was believed to be nearly 1200 to 1300 years old, from the T'ang dynasty. Examination with the unaided eye revealed an overall pearly luster, and one small area showed a dull, pearly, granular fracture. The lighter, brownish yellow layer of material on the top and bottom of the carving also displayed a weak sheen.

A precise refractive index proved difficult to obtain due to the curved surfaces and the condition of the polish; using the shadow method, however, we determined an approximate value of 1.57.

Figure 1. This interesting carving (13.3 × 3.6 × 2.5 cm) is made from clinochlore IIb, a member of the chlorite group.

Because of the difficulty of identifying such a carving with standard gemological tests, we obtained the client's permission to scrape a minute amount of powder from an inconspicuous recessed area for X-ray powder diffraction analysis. The results matched our standard pattern for clinochlore IIb, which is a member of the chlorite group.

As Klein and Hurlbut pointed out in the *Manual of Mineralogy*, 20th ed. (1977), it is extremely difficult to distinguish between the members of the chlorite group without detailed study of the X-ray and optical properties or quantitative chemical analyses. Although previous researchers have designated many varietal and species names to this extensive solid-solution group, research published in *Reviews in Mineralogy, Volume 19, Hydrous Phyllosilicates*, edited by S. W. Bailey (1988), recommends that only the species names—clinochlore, chamosite, pennantite, nimite, and baileychlore—be used for members of the chlorite group.

Therefore, on the GIA Gem Trade Laboratory identification report for the carving shown in figure 1, we stated: "The X-ray diffraction pattern of this material matches our standard pattern of CLINOCHLORE IIb, a member of the CHLORITE GROUP."

RK and Christopher P. Smith

Editor's Note: The initials at the end of each item identify the contributing editor who provided that item.

Treated-Color DIAMOND with Natural Radiation Stains

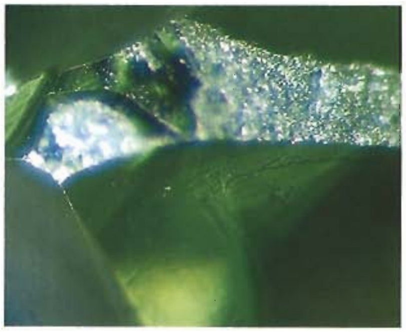
When green diamonds are submitted to the Gem Trade Laboratory, we look for, among many other things, physical characteristics that indicate whether the color is natural or produced by treatment. One indication that a polished diamond had been exposed to radiation in nature is the presence of green or brown radiation stains on a natural surface left by the cutter. It is known that these stains develop when the diamond crystal is exposed to alpha-particle radiation within the earth. However, they cannot be considered proof that the green body color is of natural origin, because alpha rays penetrate only a few tenths of a millimeter in diamonds. The stains will remain green unless the diamond is exposed to heat, either naturally or artificially, and will change to brown at about 500°C.

During routine examination of a 0.82-ct dark green marquise brilliant, the East Coast laboratory observed dark green natural radiation stains on the girdle at each point (figure 2). However, the uniform dark green color of the diamond, possibly the result of neutron irradiation, caused us to suspect that it might have been treated. In fact, we concluded—on the basis of its characteristic spectrum and uniform coloration as seen in immersion—that this diamond was treated. This stone may have been carefully selected for treatment because it had natural radiation stains; perhaps it was a pale green diamond that the treaters wanted to "enhance." It is also possible that the treaters were not aware of the stains.

If this diamond had been annealed following irradiation, the radiation stains would have turned brown and the body color would have become orange to yellow. *DH*

Figure 3. This vase, which measures 25.0 × 16.4 × 9.0 cm, was carved from an unusual color of massive grossularite garnet.

Figure 2. Natural dark green radiation stains were seen on the girdle at each point of this 0.82-ct treated green diamond. Magnified 30×.



Massive GROSSULARITE GARNET Carving

An odd-color vase, carved in an oriental flora-and-fauna motif, was recently submitted to the West Coast laboratory for identification (figure 3). It was a translucent mottled brownish yellow to brown with grayish white areas and some whitish yellow veins; the moderate polish and subvitreous luster suggested a rather hard material.

Spot refractive index readings taken from three different locations gave values of approximately 1.74. For the most part, the vase was inert to both long- and short-wave ultraviolet radiation, although some of the whitish yellow veins and grayish white areas fluoresced moderate to strong yellow to both wavelengths. A diagnostic spectrum could not be obtained with the hand-held spectroscope. When the vase was examined with the polariscope, we noted an aggregate reaction.

Because the standard gemological tests that could be conducted on this material were inconclusive, we decided to scrape a minute amount of powder from an inconspicuous area for X-ray powder diffraction analysis. The resulting pattern matches the standard pattern for grossularite garnet. Massive grossular garnet is not commonly seen in the lab as carvings. A carving of the same material, although green in color, was reported in the Spring 1985 Lab Notes section.

Patricia Maddison

Heat-Damaged JADEITE

A 14.85 × 11.75 × 4.20 mm jadeite jade cabochon set in a woman's ring was submitted to the East Coast laboratory for a damage report. The client was concerned about a change in appearance that was noticed after the ring had been repaired. The discolored area around the girdle was most apparent with transmitted light (figure 4). In addition, when the stone was exposed to long-wave ultraviolet radiation, the discolored area fluoresced pale blue (figure 5).

We have encountered heat-damaged jadeite before (see the Summer 1982 Lab Notes), but in that case the discoloration was fairly random. We nevertheless suspect that the change in appearance of the present stone is also related to heat. Heat alone may have been the culprit, or the stone may have received the customary paraffin bath during manufacture and the heat partially removed the paraffin. It is possible that the original appearance could be restored by another paraffin bath, although there was no evidence of paraffin present at the time the stone was tested. In any case, the person who performed the repair could have avoided the damage by simply removing the stone before heat was applied to the setting. *GRC*

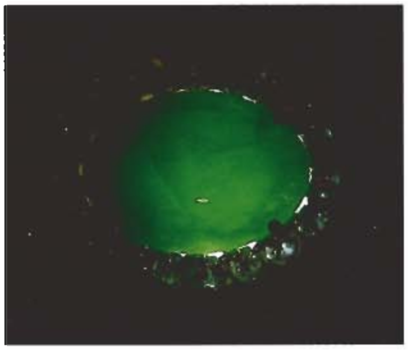


Figure 4. In transmitted light, discoloration apparently caused by exposure to excess heat is evident around the girdle of this 14.85 × 11.75 × 4.20 mm jadeite jade cabochon.

Figure 5. When the stone shown in figure 4 was exposed to long-wave U.V. radiation, the discolored area fluoresced pale blue.

Banded LAPIS LAZULI

One of our *Gems & Gemology* subscribers recently gave the West Coast laboratory the opportunity to examine and photograph the lapis lazuli cabochon ring shown in figure 6. Note the very prominent curved banding, easily seen with the unaided eye, that runs across the entire curved surface of the 19.5 × 14.7 × 8.25 mm stone. The subscriber had read with interest the entries in the Spring 1988 and Summer 1990 Lab Notes sections, which described similar, smaller cabochons of banded lapis. This stone had a spot R.I. of 1.51 and a vague reading (from calcite) at 1.48 to 1.65, was inert to long-wave U.V. radiation, and had a somewhat patchy, moderate chalk whitish green reaction to short-wave U.V.—all of which is consistent with lapis lazuli. Testing with an acetone-soaked cotton swab established that this piece was not dyed.

With low magnification (10×) and oblique fiber-optic illumination, we determined that the curved bands in this stone—as with the two previously examined by the laboratory—were comprised of layers of densely packed dark blue grains alternating with layers of light blue, near-colorless, and dark blue grains. The space between the alternating bands ranged from approximately 0.3 to 0.6 mm. *RK*

Figure 6. Parallel curved banding is readily apparent in this 19.5 × 14.7 × 8.25 mm lapis lazuli cabochon.

Unusually Large Worked and Plugged Cultured PEARL

An unusually large (32.20 × 25.68 × 21.10 mm; 96.00 ct) baroque pearl was submitted to the East Coast laboratory for identification (figure 7). Because of its size, we originally speculated that it might have been natural, as cultured pearls this large are very rare.

However, an X-radiograph revealed a relatively small shell bead, about 9.5 mm in diameter, as the nucleus (figure 8). In addition, we observed that what was apparently a groove or opening in the original cultured pearl had been filled with a cement-like material. The area around the "plugged" spot appeared to have been buffed.

If this cultured pearl were to be drilled, care would have to be taken to drill into the shell nucleus. If the drilling were to extend into a hollow space, the pearl could fracture.

DH

QUARTZITE and DOLOMITE Bead

Several colored stone dealers have remarked that black is currently fashionable and, thus, that there is a demand for jewelry with black gems. Some dealers have told us that the dyed black chalcedony traditionally used is sometimes difficult to find, so that substitutes may be called for. Such was the case with the black pear-shaped bead shown in figure 9.

Initial testing at the East Coast lab indicated that the material was a carbonate; with the spot method, the bead displayed the typical red-to-green blink in the refractometer, and gave a spot reading of 1.66. A tiny drop of dilute hydrochloric acid applied to an inconspicuous area of the bead produced an effervescent reaction. The specific gravity, obtained hydrostatically, was 2.74. Because these results could apply to several carbonates and various rock mixtures, we performed an X-ray powder diffraction analysis. This test proved that the material was a rock consisting principally of dolomite with some quartzite.

Usually, dolomite will not effervesce to room-temperature hydrochloric acid, but it may do so if the dolomite consists of fine-grained crystals, as was the case with this bead.

DH

Figure 7. At 32.20 × 25.68 × 21.1 mm, this is an unusually large cultured pearl.

Figure 8. Note the small shell bead in the large cultured pearl shown in figure 7.

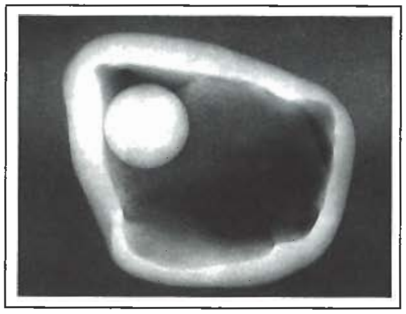


Figure 9. Testing proved that this 15.2 mm (diameter) × 25.1 mm (long) bead was a rock consisting mainly of dolomite with some quartzite.

Coated SAPPHIRE

With the proliferation of diffusion treatment, heat treatment, and the filling of cavities in corundum, the laboratory is particularly diligent when examining rubies and sapphires for enhancement.

Recently, a client submitted to the East Coast lab a medium-tone yellowish orange sapphire with the comment that "something did not look right about the color." The oval mixed cut measured approximately 6.80 × 4.90 × 3.36 mm and weighed 0.98 ct.

The R.I. of 1.762–1.770 identified the stone as corundum, and the presence of fluid-filled healing fractures confirmed it to be natural sapphire. However, no absorption features were visible with a desk-model spectroscope, and there was no reaction to long-wave ultraviolet radiation, indicating a treated color. Further, this stone showed no pleochroism, which is inconsistent with this depth of color even in a heat-treated sapphire. Subsequent examination of the stone in reflected light revealed purple iridescence on the pavilion facets (figure 10), which is unknown in natural sapphire, while a diffused darkfield environment revealed color concentrated along the edge of the pavilion surface. We concluded that the stone had been coated.

In an attempt to analyze the surface color concentration on the pavilion, GIA Research performed a qualitative chemical analysis by

Figure 10. Purple iridescence on the pavilion of this medium-dark 0.98-ct yellowish orange sapphire suggests that it has been coated.

Figure 11. After the sapphire shown in figure 10 had been soaked at room temperature for five hours in concentrated HCl, the depth of color was reduced considerably.

Figure 12. With additional soaking in HCl heated to a low temperature, the "yellowish orange" sapphire became completely colorless.

EDXRF. The analysis revealed Fe as the most abundant trace element, with small amounts of K, Ca, Ti, and Ga. A visible-range absorption spectrum of the stone, taken with a Pye-Unicam Model 8800 spectrophotometer, showed a sharp feature at 387 nm that is related to Fe^{3+}, and increasing absorption toward the ultraviolet starting about 500 nm. These results are consistent with natural-color orange sapphire and so did not, by themselves, help characterize the coating.

With the client's permission, we soaked the stone in concentrated hydrochloric acid at room temperature for five hours (figure 11). The depth of color was greatly reduced, although some of the coating remained on the pavilion. These more resistant areas were on facets with deep polishing lines or scratches. To complete the cleansing, we soaked the stone in more HCl at about 50°C for another two hours, at which point it was entirely colorless (figure 12). The beginning of increasing absorption in the visible spectrum shifted down to about 400 nm, but the sharp Fe^{3+} feature was unchanged; this suggests that the orange color of the coating resulted from broad absorption in the green and blue portions of the spectrum.

Although surface coatings such as the "Aqua Aura" process reported on topaz and quartz (see, e.g., *Gems & Gemology*, Fall 1990, p. 234, and *Journal of Gemmology*, April 1989, pp. 364–367) are commercially available, this is our first encounter with such a coating on corundum.

Recently, there has been a great deal of research and development in dry thin film technology and its application in jewelry manufacturing (e.g., *American Jewelry Manufacturers*, May 1991). We would not be surprised to see a variety of coatings on more types of gems in the coming years. *TM and Ilene Reinitz*

Twinned SYNTHETIC SAPPHIRES

Within a short period of time, the East Coast laboratory encountered two synthetic sapphires that the clients had assumed were natural because of the presence of repeated twinning (figure 13) and what appeared to be boehmite needles contained within the planes (figure 14).

Straight twinning lamellae were considered proof of natural origin until 1920, when this feature was noted as an anomaly in synthetic sapphire by Sandmeier, and corroborated by W. Plato. For a detailed description of this phenomenon, see the article "Polysynthetic Twinning in Synthetic Corundum," by W. F. Eppler (*Gems & Gemology*, Summer

Figure 13. The repeated twinning evident in this 17.95 × 13.90 × 6.80 mm synthetic blue sapphire had led the client to believe it was natural. Magnified 10×.

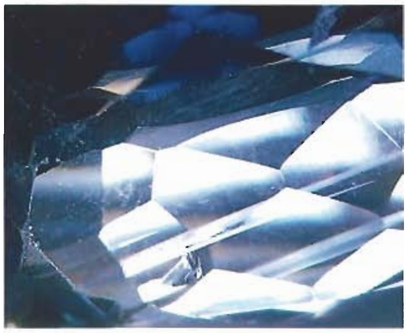


Figure 14. The presence of what appeared to be boehmite needles together with repeated twinning also created problems in the client's identification of this 26.00 × 13.12 × 9.20 mm reddish orange sapphire. Magnified 23×.

1964). More recently, we reported on the presence of these phenomena in the Summer 1984 (p. 111) and Spring 1989 (p. 38) Lab Notes sections.

We conclusively identified the two recent examples described above as synthetic sapphires by the presence of small gas bubbles and curved growth bands, which we observed with magnification and diffused darkfield illumination. The appearance of repeated twinning in a synthetic sapphire can prove to be an identification challenge, especially when the stone in question may have been heat treated. Thermal treatment can diminish curved color banding, so that it is only evident when the stone is examined with immersion. *TM*

FIGURE CREDITS

Figure 1 is by Robert E. Kane. Figures 2, 4, 5, 7, and 10-14 are by Nick DelRe. Maha Smith took figure 3. Figures 6 and 9 are © GIA and Tino Hammid. The X-radiograph in figure 8 is by Robert Crowningshield. The Historical Note photo of the heart-shaped inclusion in diamond is by A. de Goutière.

A HISTORICAL NOTE

HIGHLIGHTS FROM THE GEM TRADE LAB 25, 15 AND FIVE YEARS AGO

WINTER 1966

The New York lab reported on some of Chatham's new synthetic flux-grown ruby. All four of the crystals examined contained natural sapphire seeds. The natural-seed centers were much more opaque to short-wave ultraviolet radiation than was the surrounding synthetic material.

Another interesting item concerned Mexican topaz that had been treated in the atomic pile at Brookhaven, New York, and altered to a very dark brown. This material may have been the predecessor of the treated blue topaz that is so much in evidence today. It would have been interesting to see if these stones turned blue with heat treatment, as does the topaz irradiated by today's methods.

Although the Los Angeles lab reported on different types of synthetic sapphires and on a one-plus-carat uvarovite crystal from Quebec, the most interesting item was a parcel of stones that arrived at the lab with a most fascinating letter. The client wrote that he had located a single deposit in California that produced blue and pink sapphires, green and brown peridot, zircon, almandite, diopside, enstatite, spinel, and even tiny diamond crystals.

The parcel of stones he submitted did, in fact, contain these materials, but only the small diamond could be considered gem quality. He claimed that the deposit was a pipe with a quartz-feldspar dike intruding into it. Naturally, he was unwilling to be more specific as to location.

WINTER 1976

The Santa Monica laboratory had occasion to examine and photograph a very unusual laser-drilled diamond. Usually, when a diamond is laser drilled in an attempt to enhance its clarity, the drilling is done from the pavilion. This stone had between 25 and 30 drill holes through the table! Although not as readily apparent as one might expect when viewed perpendicular to the table, they were quite evident when viewed from any other angle.

The New York laboratory reported on various colored diamonds, both treated and natural. In addition, one fascinating photograph showed how the location of an inclusion can seriously affect the apparent clarity of a stone. In this instance, the single small inclusion was reflected in virtually every facet of the host diamond. If this inclusion had not been in this exact position, the stone would have looked like a VS_2 rather than an SI_2.

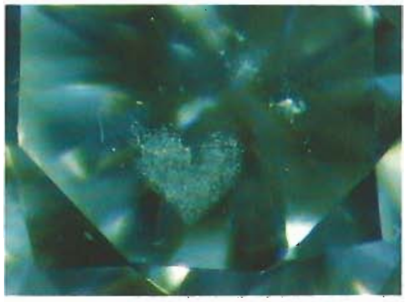
WINTER 1986

The East Coast laboratory illustrated and discussed the separation of synthetic from natural amethyst by the presence of the twinning that occurs in natural amethyst and/or the spicules that are sometimes seen in hydrothermally grown synthetic amethyst

GIA's permanent collection, in Santa Monica, received a gift of two (rough and cut) rare clinohumites. The crystal weighs 1.72 ct and the cut stone, 0.39 ct.

Since this is the Winter issue, with St. Valentine's day just around the corner, it seems appropriate to show again the very rare heart-shape inclusion in a small (0.015 ct) diamond that was brought to our attention by Mr. A. de Goutière of Victoria, B.C., Canada.

Note the heart-shaped cloud in this 0.015-ct brilliant-cut diamond. Magnified 12×.



GEMNEWS

JOHN I. KOIVULA AND ROBERT C. KAMMERLING, EDITORS

DIAMONDS

Botswana expands into diamond manufacturing. Through Debswana, the joint diamond-mining venture of De Beers and the government of Botswana, a cutting industry is being developed in that southern African nation. The Teemane Manufacturing Company has more than 100 trainees at its newly established school in Serowe. This is the first cutting and polishing venture in the country. (*Diamond Intelligence Briefs*, October 10, 1991, p. 815)

Large Chinese diamond. The Wafangdian Diamond Mine in northeast China, one of the latest to go on-line in that country, recently produced a 60.6-ct stone. The crystal, named Fenggu Number 1, is one of several stones larger than 10 ct. recovered from this locality. (*Diamond Intelligence Briefs*, July 11, 1991, p. 784)

Diamond center planned for China. A new diamond "town," to be located in the Pudong area of Shanghai, China, is being planned for completion in 1995. More than 30 foreign firms are currently negotiating to participate in diamond trading and construction of diamond-processing plants. The project is supervised by the Shanghai Arts and Crafts Import and Export Company. (*Rapaport Diamond Report*, January 11, 1991, p. 8)

Data suggest strong, changing U.S. diamond market. Despite the sluggish economy and the Gulf War, U.S. demand for diamonds remained strong during the first six months of 1991. This assessment is based on monthly statistics from the U.S. Bureau of Mines as analyzed by Lloyd Jaffe, Chairman of the American Diamond Industry Association (ADIA).

Overseas shipments of cut goods by caratage rose substantially—15.7%—compared to the first half of 1990, although in terms of dollar value this was a decrease of about 0.1%. U.S. exports to top trading partners in Belgium, Hong Kong, Japan, Israel, and Switzerland continued to be strong, but the overall average per-carat price of loose fashioned stones exported fell 13.7% to $1,366. By comparison, imports of loose fashioned diamonds in the first half of 1991 increased in terms of both dollar value and weight compared to the same period last year: up 4.5% to $1.65 billion and up 9.4% to 3.13 million carats.

The data also suggest that many U.S. diamond merchants are shifting their inventories to accommodate market changes brought about by lower levels of disposable income. For example, the average per-carat price of loose cut stones from India, a major source of smaller, less expensive goods, dropped 14% to $263; and the average per-carat price of goods from Israel, a key source of middle-range diamonds, dropped to $791.

Diamond factory to open in Dubai. What reportedly will be the first diamond factory in the Middle East outside Israel is currently being set up in Dubai, one of the United Arab Emirates. Equipment obtained in Antwerp has already been installed and, initially, 40 workers will be employed. Citi Diamond Co. will produce finished stones for export in the 0.05–0.50 ct range. (*Diamond International*, September/October 1991, p. 26)

G.E. synthesizes large carbon-13 diamonds. In October 1991, the General Electric Research and Development Center in Schenectady, New York, announced the synthesis of the first large, gem-quality diamonds composed almost entirely—99%—of the isotope carbon-13. By comparison, natural diamonds are composed almost entirely of the lighter isotope carbon-12. Carbon exists in nature as these two stable isotopes; but the natural abundance of carbon-13 is only 1%.

The essentially colorless carbon-13 synthetic diamonds, in crystals up to 3 ct, were produced by a two-step process that involves both chemical vapor deposition and high-pressure technology. This is the same technique G.E. used in 1990 to produce the first gem-quality synthetic diamonds enriched with 99.9% carbon-12. In 1970, G.E. scientists produced their first carbon-13-enriched gem-quality diamond using high-pressure technology. Its purity level, however, was only 91% carbon-13, short of the desired goal.

High-resolution X-ray measurements, performed by Ford Motor Company scientists in Dearborn, Michigan, revealed that these new synthetic diamonds contain more atoms per cubic centimeter at room temperature than any other solid known to exist on earth. Experiments carried out by Ford researchers showed that, as the carbon-13 concentration is increased, the interatomic distance decreases slightly, resulting in a corresponding increase in atomic density. This is an important discovery (and one expected on theoretical grounds), as some scientists speculate that carbon-13 diamonds may be harder than natural diamonds. G.E. scientists will be making comparative measurements to test this concept.

One unexpected discovery made by the Ford researchers was the exceptional perfection of the crystal structure of G.E. synthetic diamonds of all compositions, approaching that of silicon semiconductor crystals. Because improved crystal quality translates into improved electronic properties, the Ford discovery may stimulate development of new diamond-based electronic devices.

Guinea's Aredor produces another large diamond. A 192.9-ct gem-quality diamond was recovered from the Aredor alluvial diamond mine in May 1991. It is being sold through IDC Diamond Holdings in Antwerp. This reportedly is the fifth gem-quality stone of 100 ct or larger that has been recovered from this mine since 1986. (*Mining Journal*, July 26, 1991, p. 67)

Indonesian production on line. Indonesian Diamond Corp. reports that production at its southeastern Kalimantan holdings began in October 1991. In the first 17 days of operation, 476.6 ct of diamonds were recovered from the treatment of 4,740 m^3 of gravel. The current project area has a proven reserve of 2.9 million m^3, with an average 0.102 ct of diamond per cubic meter. There is a further indicated resource of 15.3 million m^3 and an inferred 29.4 million m^3 in an adjacent area. When two processing plants are fully operational, IDC will be able to process 54,000 m^3 of gravel per month for a recovery of about 5,400 ct of diamonds. (*Mining Journal*, November 8, 1991, p. 355)

"Nickel thermometer" for diamond exploration. Chrome-pyrope garnet is widely used in diamond exploration as an indicator mineral. Quantitative evaluation of potential diamond sources has involved searching for low-calcium, high-chromium (G10) harzburgitic garnets. Unfortunately, this method has drawbacks: Some diamondiferous pipes, such as at Argyle, contain few of these garnets, while other pipes rich in them are barren of diamonds.

Higher-calcium chrome pyropes (G9 garnets) have largely been ignored, although they are typically more abundant in heavy mineral concentrates from both kimberlites and lamproites and provide considerable information on diamond potential. The CSIRO Division of the Exploration Geoscience Diamond Project has developed a simple technique to evaluate the diamond potential of kimberlites and lamproites that uses proton-microprobe (PIXE) trace-element analysis of a relatively small number of G9 garnet grains. The nickel content, which is very sensitive to temperature of formation, is used with a conversion factor to estimate depth of formation. This knowledge, in turn, makes it possible to determine which garnets should co-exist with diamonds. The technique appears to be a more reliable indicator of potential diamond grade than the presence or absence of G10 chrome pyropes. (*Mining Journal*, March 22, 1991)

Figure 1. These new "Royal" cuts (0.70 ct to 2.32 ct), are modified brilliant cuts with outlines that resemble the traditional pear, oval, and marquise. Photo © Tino Hammid.

New "Royal" diamond cuts. Raphaeli-Stschik, an Israel-based firm that specializes in fancy shapes, recently unveiled their new Royal Line diamond cuts. The three trademarked cuts—the Duchess, the Baroness, and the Empress—were reportedly designed to take advantage of relatively flat rough. According to Gershon Stschik, who co-developed the cuts with Chumi Raphaeli, certain rough led them to design diamonds that were significantly wider at the top than either traditional fancy shapes or rounds. Stschik says the stones are "top heavy" in comparison to traditional fancy shapes, which makes the new cuts appear 50% larger than traditional fancies of the same carat weight.

Recently, GIA received a few samples of these new cuts for inspection from the U.S. distributor, Suberi Bros., New York. The Duchess cut, a modification of the marquise, is an elongated, hexagon-shaped brilliant; the Empress cut is a seven-sided modified pear brilliant; and the Baroness cut is an octagonal brilliant that resembles an oval (figure 1). All three cuts have traditional crown and pavilion facet arrangements.

COLORED STONES

Hairy insect in amber... Dr. George O. Poinar, Jr., insect paleontologist at the University of California at Berkeley, recently described an unusual fossil insect found in amber from the Dominican Republic. The insect (figure 2) possesses what is perhaps one of the most unique offense-defense systems nature has yet to devise. Sometimes called a "hairy bug," it is scientifically classified in the family Reduvidae, subfamily Holoptilinae, of which it is the only known fossil member in the New World. Its defense system consists of the stout, brittle hairs that protect the limbs from attack by ants. The offensive "weaponry" consists of a gland on the ventral side of the abdomen that releases a secretion that both attracts ants and tranquilizes them so they can be devoured.

Czechoslovakian conference yields valuable information. In September 1991, Karin N. Hurwit of the GIA Gem Trade Laboratory, Santa Monica, attended Intergem, a gemological conference hosted by the Geological Survey of Prague in conjunction with the Czechoslovak Academy of Sciences and "Granát," a Czechoslovakian commercial enterprise. Ms. Hurwit provided the following information from exchanges with various researchers at the gathering.

Figure 2. This unusual 4.7-mm long "hairy bug" is encased in amber that was found in the Dominican Republic. Photo by Dr. George O. Poinar, Jr.

Figure 3. This fine 3 mm × 1.4 mm ruby crystal in matrix is from a recently discovered deposit in the South Ural Mountains of Russia. Photo © GIA and Tino Hammid.

Dr. A. Kissin, from the Ural branch of the Academy of Science, Ekaterinburg, Russia, released information on a recently discovered ruby deposit in the "Kootchinskoye" ore mine complex, located in the South Ural Mountains north of Magnitogorsk. Although rubies were first found in this area in 1979, not until late August 1991 did geologists locate the important new find that promises to produce high-quality stones. Dr. Kissin indicated that the host rock is a magnesium-calcite marble, which is believed to provide the best environment for the growth of fine-quality ruby crystals. Dr. Kissin generously donated a few samples to GIA for examination, including a fine tabular ruby crystal in matrix (figure 3) and several carats of extremely small loose crystals, also of exceptionally fine color.

Dr. Vladimir Balitsky, of the Laboratory for Mineral Synthesis at the Institute of Experimental Mineralogy, Moscow, discussed and displayed synthetic malachite. Although the Fall 1987 issue of *Gems & Gemology* contains a detailed article on this material (of which Dr. Balitsky was the senior author), GIA staff members had not yet had an opportunity to examine this gem-quality synthetic first-hand. However, Ms. Hurwit was able to purchase a large specimen for GIA's collection. This material is being studied and any new information will be reported at a later date.

In a discussion with scientists from the St. Petersburg State University, Ms. Hurwit learned that synthetic opal is being produced commercially in Russia. GIA is arranging to obtain samples of this material for investigation, the results of which will be published in an upcoming issue of *Gems & Gemology*.

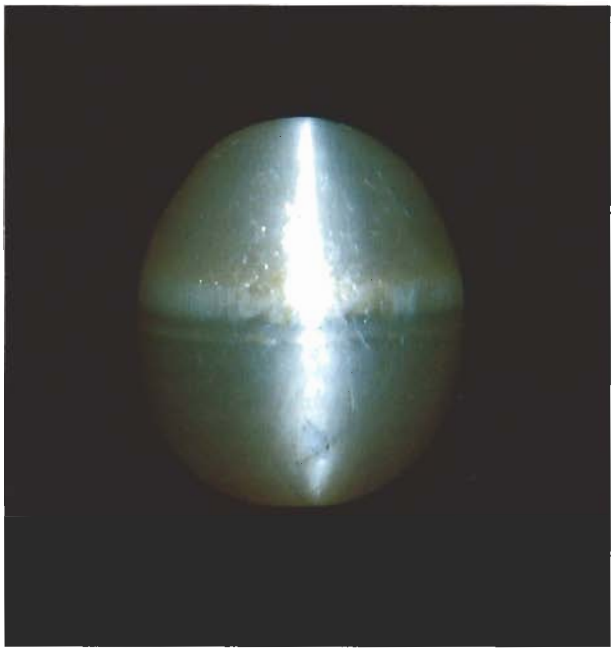


Figure 4. This 3.65-ct chrysoberyl (9.69 × 8.14 × 4.54 mm) exhibits a chatoyant band along its longer dimension, crossed at right angles by a growth band. Courtesy of Edward J. Gübelin; photo by Maha Smith.

Novel chrysoberyl "cross" cat's-eye. Dr. Edward J. Gübelin shared with the Gem News editors a most unusual chrysoberyl in his collection (figure 4). The yellowish grayish green oval cabochon exhibits a typical bright chatoyant band down its longer dimension. This is crossed at a right angle by another band. The second band, however, is not produced by reflection and scattering of light off parallel acicular inclusions. Rather, it is a distinct growth band that has a noticeably different color from that of the remainder of the stone.

Attractive Tanzanian diopside. The transparent, faceted diopside most often seen in the trade is the "chrome" variety from Russia. This material typically exhibits a highly saturated, dark green body color that would most likely be confused visually with the bright green tourmaline from East Africa that is marketed as "chrome tourmaline."

The 1.18-ct diopside in figure 5, however, was cut from rough reported mined in the Lelatema Hills of northern Tanzania. The stone is lighter in tone and has a stronger yellow component to its color than what we expect to see in transparent diopside. It reminded us of some green grossular garnet from Tanzania or fine-quality peridot from Burma, although we have seen somewhat similar-appearing diopside from China (see the Summer 1989 Gem News column entry "Colored stone update from China," pp. 111–112).

Gemological testing confirmed the identity as diopside, with R.I., birefringence, and S.G. within the ranges reported in the literature for this gem species. Examination with a dichroscope revealed weak pleochroism of brownish green and bluish green. The stone fluoresced a weak reddish orange to long-wave U.V., and a strong, slightly chalky yellow-green to short-wave U.V. No distinct absorption features were noted with a desk-model prism spectroscope. Magnification revealed graphite plates and fluid inclusions in a plane parallel to a cleavage direction.

Fine emerald/green beryl from Nigeria. Mike Ridding of the firm Silverhorn, in Santa Barbara, California, brought to our attention an important find of large emerald and green beryl crystals from the area of Jos, Central Plateau State, Nigeria, that was made in December 1990. We examined a number of these crystals, which display well-formed crystal faces (figure 6). Most of the material reportedly went to Idar-Oberstein, where faceted stones as large as 20 ct have been cut.

New production of demantoid garnets from Russia. Bill Larson, of Pala Properties International in Fallbrook, California, reports that demantoid garnets apparently are again being mined in the Ural Mountains of Russia. At the Munich gem fair last fall, Mr. Larson obtained more than 100 grams of rough material that reportedly had been recovered recently from the same region of the Urals where the historic deposits were mined. The best of the

Figure 5. A mine in the Lelatema Hills of northern Tanzania was the source of this 1.18-ct diopside. Photo by Maha Smith.

Figure 6. These emerald/green beryl crystals (standing—55 mm long, 200 ct; lying—75 mm long, 100 ct) were mined in Nigeria in late 1990. Photo by Maha Smith.

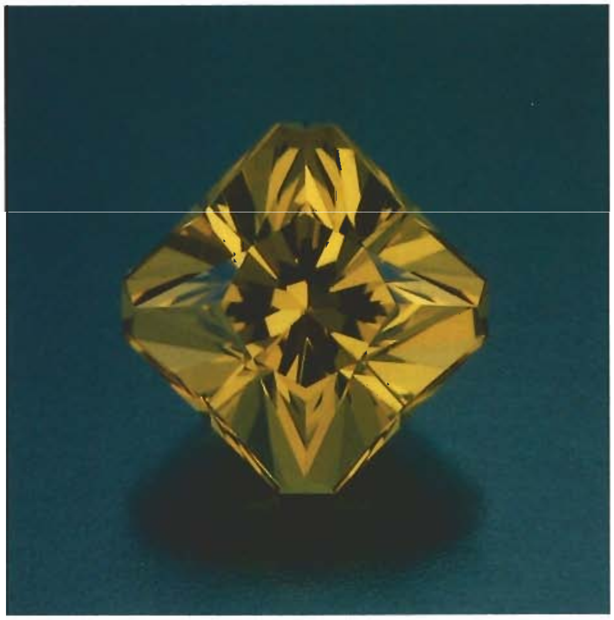
material appears to be the deep rich green for which Russian demantoid garnets are noted (figure 7). Less than 10% of the parcel he obtained fit this category, however; most of the material was a lighter green.

Tanzanian yellow grossular garnets. Although best known for its hessonite and tsavorite varieties, grossular garnet occurs in a wide range of colors. Recently, private collector Don Clary submitted to GIA's Research Department three stones from Tanzania for investigation. The largest of the three stones, a 3.17-ct barion cut (figure 8) was studied in detail in an attempt to understand the origin of its unusual color. EDXRF spectroscopy detected the presence of titanium, manganese, and iron. U.V.-visible absorption spectroscopy revealed absorption increasing toward the ultraviolet, with three sharp lines at approximately 407, 418, and 428 nm, and a doublet at about 370 nm. These sharp bands are typical of Mn^{2+} in the distorted cubic site in garnets. We concluded, therefore, that the yellow color of these Tanzanian grossularite garnets is primarily due to manganese (Mn^{2+}), with no significant contribution from iron.

Large tsavorite garnet from Tanzania. The Summer 1990 *Gems & Gemology* contained a report titled "Well-Formed Tsavorite Gem Crystals from Tanzania" that focused on high-clarity material recovered from the Karo pit of the tanzanite mining belt. The largest faceted stone mentioned (and illustrated) in that report was 14.84 ct.

Figure 7. Demantoid garnets are again being mined in Russia. This 0.31-ct demantoid represents some of the finer recent material seen. Photo © GIA and Tino Hammid.

Figure 8. The color of this 3.17-ct grossular garnet from Tanzania is primarily due to manganese. Photo by Robert Weldon.



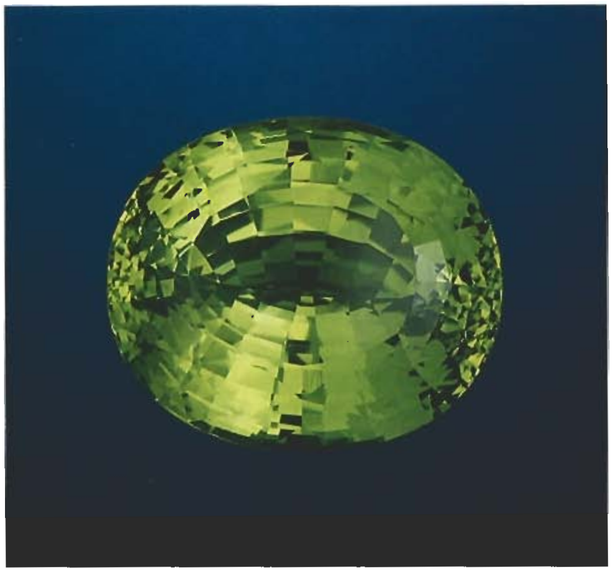


Figure 9. At 23.56 ct, this tsavorite from the tanzanite deposits at Merelani, Tanzania, is exceptionally large for this gem variety. Courtesy of Dr. Horst Krupp; photo by Shane McClure.

Recently, the GIA Gem Trade Laboratory's Robert Kane, senior author of the article, brought to our attention an even larger faceted stone from this deposit. The 23.56-ct oval mixed cut (figure 9) is exceptionally clean: Microscopic examination revealed only weak graining and three acicular inclusions. It was reportedly cut from a well-formed crystal similar to those described in the article.

"Recycled" ivory. Increased awareness of, and concern for, endangered species over the past several years has resulted in a number of moves to ban trade in such organic gem materials as tortoise shell and elephant ivory. This has resulted in a search for acceptable substitutes. A number of replacements for elephant ivory have been promoted, from "fossilized" ivory–mastodon and mammoth tusks–to "vegetable" ivory, particularly tagua nuts. Laboratory-made substitutes have also been promoted, including various plastics and one reportedly effective composite material from Japan.

At a recent gem and mineral show, one of the editors came across a novel scheme to market natural elephant ivory while assuring prospective buyers that it did not come from recently killed elephants. Sold as "recycled" ivory for use in small engravings and plaques, the pieces in question were actually the thin ivory veneer removed from old piano keys!

More on Peruvian opal. The Summer 1991 Gem News column included a brief entry on an attractive blue opal that reportedly originates in the Andes Mountains of Peru. Subsequently, the editors obtained additional information from Eugene Mueller, president of The Gem Shop, a Cedarburg, Wisconsin, firm that markets this material.

According to Mr. Mueller, the blue opal, as well as a pink variety, is recovered from a copper mining area called Acari, located near the city of Arequipa, Peru. Some 200 to 400 kg of opal is produced each month during the six months of the year when mining takes place. The material, which occurs in seams ranging from 1 to 5 cm thick, is currently mined using simple hand methods.

Less than 10% of the total production is of the blue variety, which ranges from transparent to a "milky" translucency, and varies from a light blue-gray through blue-green to a saturated greenish blue similar to that associated with fine chrysocolla. The pink material varies from translucent to almost opaque, in hues ranging from a light brownish pink through a purer pink; some exhibits a color reminiscent of rhodochrosite. The pink material (figure 10) is reportedly the tougher of the two color types. Gemological testing revealed properties consistent with

Figure 10. This 15.54-ct opal cabochon comes from the Acari copper mining area near Arequipa, Peru. Photo by Maha Smith.

opal for both types. Both blue and pink materials commonly contain dendritic inclusions; prior to the discovery of these colored varieties, colorless dendritic opal mined in this area had reached the U.S. market.

Antique portrait ring. An unusual late-19th-century portrait ring, recently auctioned at Sotheby's in Beverly Hills, California, was brought to our attention by Carol Elkins, a graduate gemologist and assistant vice-president of jewelry for Sotheby's. The yellow gold and platinum ring, highlighted by small rose- and single-cut diamonds, contains as its center stone an oval flat-topped tablet of very slightly yellowish white translucent chalcedony that measures approximately 22 × 16 mm. The chalcedony is an interesting type of "cameo" stone in that there is an excellent brown-colored portrait of George Washington printed on, or stained into, its surface (figure 11). Microscopic examination revealed that the portrait does in fact penetrate the surface by a fraction of a millimeter. The fine detail of the portrait, along with the noted penetration into the stone, suggest that the image was produced by means of a photographic process. In such a process, the porous chalcedony was probably first chemically treated with a light-sensitive substance and then exposed, much as one would print using photographic printing paper. This is the first such example of photoprinting on a gem material that we have encountered. However, we recall seeing a light-sensitive aerosol spray that could be used to turn various surfaces into photographic printing "paper."

Figure 11. This antique chalcedony ring is decorated with what appears to be a photoportrait of George Washington. Photo courtesy of Sotheby's, Beverly Hills, CA.

More synthetics sold as natural ruby in Vietnam. We recently were shown the five pieces of rough and one preform illustrated in figure 12, which were reportedly purchased in Vietnam as natural ruby. All six stones showed the spectrum typical of both natural and synthetic ruby when examined with a handheld type of spectroscope. The smallest piece of rough was easily identified as natural on the basis of its inclusions (which are described in detail in the article "Rubies and Fancy Sapphires from Vietnam," by Robert E. Kane et al., in the Fall 1991 issue of *Gems & Gemology*). Microscopic examination of the preform readily revealed the presence of curved striae and gas bubbles typical of Verneuil synthetics. Because of the irregular surfaces and reduced transparency of the "crystals," X-ray fluorescence analysis was used in conjunction with microscopy to test the remaining four pieces of rough. All proved to be synthetic; curved striae were seen in two of the four pieces. Curved striae are generally quite difficult to discern in "rough" synthetic rubies.

It appears that the pieces of synthetic rough had been intentionally worked, perhaps cobbed as well as tumbled, to look like natural rough. Such fraudulent practices have been seen in localities all over the world, and we have examined several examples of faceted synthetic rubies that were purchased in Vietnam as natural stones. These are the first examples of synthetic ruby "rough" that we have examined at GIA.

Update from Sri Lanka. Gordon Bleck, a dealer who resides in Sri Lanka much of the year, has once again provided us with an update on gemstone production in that country. He informs us that, overall, gem mining is hampered by terrorist activity, particularly in remote jungle areas such as that around Okampitya. Ratnapura, however, remains relatively safe. Following are some of the recent developments and unusual gem materials Mr. Bleck brought to our attention.

Rubies have been found near Hambatota, which represents a new locality for this gem. Stones rarely reach one carat in weight, but are of an unusually good quality, with a deeper color than is usually associated with rubies from Sri Lanka.

Deep pink fancy sapphires were recently found in the Matara district, along the southern coast. Fashioned gems are rarely more than 2 ct. To date, production has been limited.

In our experience, star spinels from Sri Lanka have tended to be almost opaque and of a very dark, low-saturation purple color. According to Mr. Bleck, in 1991 star spinels of a saturated red color and a high degree of transparency were found in the Ratnapura district (figure 13).

Clean, light yellow danburite crystals have been recovered from the Nirialla River, approximately 10 km from Ratnapura, near the towns of Palawela and Nirialla. The large specimen from which the 11.52-ct pear shape shown in figure 14 was cut was found in the river bed, whereas smaller fragments come from the river bank. This newer danburite tends to be less included than earlier productions.

Among the rarities found this past year were two crystals of translucent yellowish green andradite, the larger about 2 cm across, which show a typical combination of dodecahedral and trapezohedral shape. This past year also saw the production of larger quantities of color-change spinels, sapphires, and garnets.

Mr. Bleck also encountered considerably more facetable kornerupine this past year. An outstanding example is the 17.01-ct brownish green stone from central Sri Lanka shown in figure 14. The color is unusually light in tone for a stone of this size. Cat's-eye kornerupines, which were once fairly easy to obtain in Sri Lanka, have become quite scarce. Figure 14 also shows an unusually large—5.00 ct—blue sillimanite, from Ambalapitya.

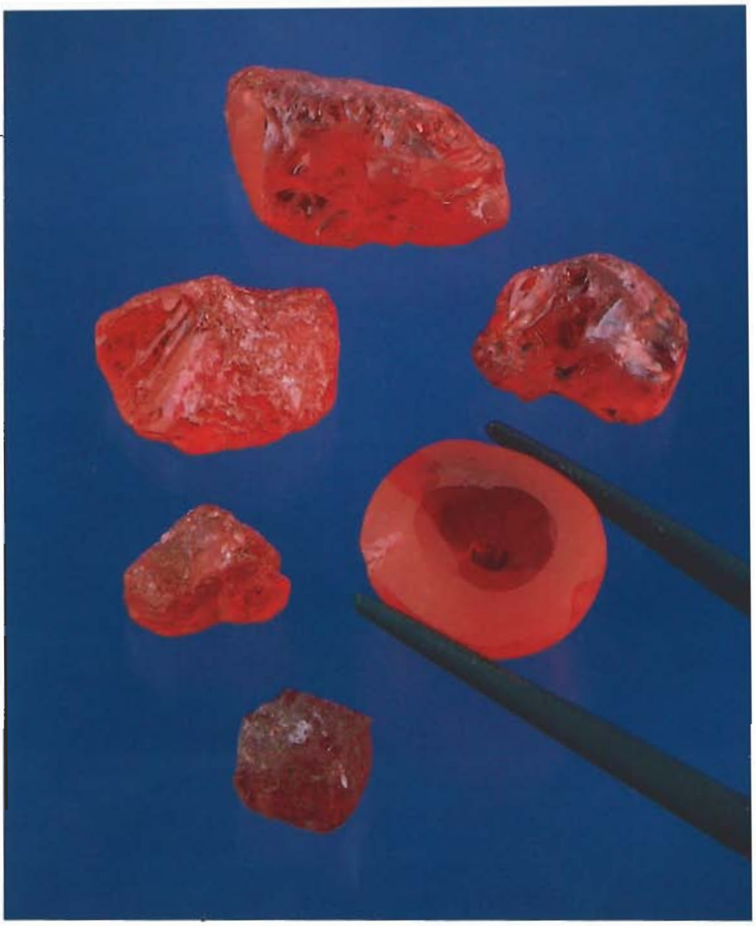


Figure 12. All six of these stones were purchased in Vietnam as natural ruby. On the basis of gemological testing and, in some cases, X-ray fluorescence analysis, the 11.44-ct preform and four of the pieces of rough (3.93–15.17 ct) were identified as Verneuil synthetic rubies; the smallest piece of rough (bottom, 3.79 ct) proved to be natural ruby. Photo by Shane McClure.

Sunstone/iolite mixture. Herb Walters of Craftstones in Ramona, California, gave us some tumble-polished samples of an intergrowth of sunstone oligoclase feldspar and iolite to examine. According to Mr. Walters, the material originated in India, from which he regularly receives large quantities of both sunstone and iolite. Rarely, however, do they encounter intergrowths like the one shown in figure 15. When these intergrowths do occur, the iolite portion is usually of the "bloodshot" type, that is, containing "hematite" inclusions.

Figure 13. This 1.12-ct red star spinel from the Ratnapura district of Sri Lanka is unusual for both its color and its high degree of transparency. Photo by Robert Weldon.

Figure 14. Recent production in Sri Lanka includes the 11.52-ct pear-shaped yellow danburite, 17.01-ct brownish green kornerupine, and 5.00-ct blue sillimanite shown here. Courtesy of Gordon Bleck; photo by Robert Weldon.

Update on Tanzanite mining. Abe Suleman of Tuckman Mines & Minerals Ltd. recently provided the Gem News editors with a detailed update of mining activity in the Merelani mineralization zone of Tanzania.

This zone, which is more than 5 km long, runs in a northeast-southwest direction. It contains four main blocks, designated A, B, C, and D, which cover old mining areas. The government has awarded mining rights to these large blocks to firms with technical expertise and financial resources in order to have mechanized, large-scale, controlled mining in the area.

Block A, at the southwest end of the deposit, measures 540 m × 850 m (1,755 × 2,770 ft.) and has been awarded to Kilimanjaro Mines. Although there are no official reports of mining activity, it is known that exploratory tunneling has begun.

Block B, measuring 845 × 1,150 m (2,750 × 3,760 ft.), includes the famous "Opec" pits (former location of the "De Souza Pit") and is the site where the green zoisite is found. It is now held by Building Utilities Ltd. Rehabilitation of some of the old pits in this block has been completed and a few are again being mined.

Block C, measuring 1,150 × 2,075 m (3,760 × 6,750 ft.), is run by Tangraph, a joint venture between Samax, Tanzania Gemstone Industries Ltd. (a parastatal body), and Africa Gems. Under their agreement, Samax takes the graphite, T.G.I. takes the gemstones, and Africa Gems handles the marketing of the gems. Apart from a few exploratory trenches, no mining activity has officially been reported.

Block D, measuring 875 × 1,460 m (2,850 × 4,750 ft.), is where the major activity is taking place. Formerly awarded to Arema Enterprise Ltd., it has since been given to the Arusha Region Miners' Association (an association of small-scale miners and prospectors) by a special order from Tanzania's Minister of Home Affairs. The block was immediately divided into small areas that were distributed among the members. This amounts to a return to small-scale individual mining: going down by rope into unventilated pits 30 to over 60 m in depth, working by the light of small kerosene wicker lamps, and bringing up the "muck" in cowhide buckets. Mr. Suleman estimates that there are roughly 350 pits being worked by some 4,000 miners, all chasing the same two or three productive mineralized zones. According to an unwritten but strictly honored law, whoever first hits the zone has the right to mine that portion of it. Thus, there ensues an underground race in which everyone is trying to dig deeper and farther than the others.

The government also marked out several small blocks southwest and northeast of blocks A and D, respectively, and has already invited offers to mine these. Reportedly, in the near future, Tanzanian firms and individuals will be allowed to peg claims to mine tanzanite on a small scale.

Although all production is supposed to pass through Arema and be sold only to authorized dealers, it has been difficult to monitor production. It is widely known in gemstone circles in Tanzania that inventories in neighboring countries are building up again.

Bicolored tourmaline with unusual color effect. Tourmaline may exhibit two basic types of color zoning. In one, color varies from the center of the crystal to the periphery, as in watermelon tourmaline. In the other type, color varies

Figure 15. This 40-mm-long tumble-polished pebble consists of an unusual intergrowth of sunstone feldspar and iolite. Photo by Maha Smith.

Figure 16. This 6.10-ct bicolored tourmaline appears orange in areas where reflections of its pink and yellow color components overlap. Photo by Maha Smith.

down the length of the crystal. The latter type is typically step cut to display zones of colors along the length of the faceted stone.

The step cut is also typically used with amethyst-citrine, the bicolored variety of quartz. Occasionally, however, we see a bicolored quartz gem fashioned in a brilliant cut. The finest of these exhibit distinct zones of amethyst and citrine color, and they may display a distinctive "peach" color that results from a blending of the two color components through internal reflection. We recently examined a tourmaline (figure 16) that reminded us of the brilliant-cut amethyst-citrines just described. The stone, brought to our attention by gemologist William Pinch of Pittsford, New York, was mined in Minas Gerais, Brazil. The 6.10-ct oval modified brilliant is bicolored, with both pink and yellow. Where reflections of the two colors overlap, the stone appears orange.

SYNTHETICS AND SIMULANTS

New laser crystals with gem potential. Apparently, firms that grow crystals for technical applications now routinely sell their scraps to recyclers and faceters. As such materials may find their way into the jewelry industry, it is prudent to keep up with developments in crystal synthesis. In January 1991, GIA's Emmanuel Fritsch attended the Lasers '91 exhibit in Los Angeles. Following are some of the developments and materials covered at the event. Many companies with exhibits at the show were marketing crystals grown in China, which must now be considered an important source of synthetic crystals.

Synoptic, a division of Litton, Airtron, grows a number of crystals by the Czochralski pulling technique. These include chromium-doped synthetic alexandrite and two materials with an orangy pink color reminiscent of "padparadscha" sapphire: an erbium-doped YAG and an erbium-doped yttrium lithium fluoride (YLF). The firm also produces three materials with a saturated "emerald" green color: YAG doped with a combination of chromium, thulium, and holmium; chromium-doped lithium calcium fluoride (LiCaF or "licaf"); and chromium- and neodymium-doped gallium scandium gadolinium garnet (Cr,Nd:GSGG). Synoptic's parent company owns Diamonair, a firm that produces cubic zirconia jewelry.

Novel synthetic star sapphire. From a gemological viewpoint, some of the most interesting gem materials are those that display optical effects referred to collectively as "phenomena." We are especially intrigued by uncommon chatoyant and asteriated gems, a number of which have been reported in the Gem News section. Recently, one of the editors purchased an unusual laboratory-grown gem: a synthetic star sapphire with an incomplete star.

Figure 17. The "hole" in the center of this 2.68-ct synthetic star sapphire makes this a most unusual phenomenal stone. Photo by Maha Smith.

Unlike most asteriated synthetics, which display well-defined rays intersecting at the apex of the cabochon, this gem has a "hole" in its star. While the rays extending up from the girdle edge are relatively sharp, they stop abruptly about one-quarter of the way from the top of the dome (figure 17). The unasteriated core area also appears to be somewhat more transparent than the remainder of the stone, which, in general, is considerably more transparent than most synthetic star sapphires and star rubies we have examined. Magnification revealed that the area of greater transparency is totally devoid of the minute spherical gas bubbles that are usually found throughout asteriated flame-fusion synthetics.

The Gem Trade Lab Notes section of the Summer 1982 *Gems & Gemology* pictures a similar effect in a synthetic star ruby, which had been cut from a section near the bottom of the boule. The nonasteriated portion of that stone was believed to represent part of the nonasteriated seed crystal used to initiate growth of the boule. This explanation might also account for the similar effect noted here.

ENHANCEMENTS

More on Opticon as a fracture filler. Although the article in the Summer 1991 *Gems & Gemology* on fracture filling focused on emerald ("Fracture Filling of Emeralds: Opticon and Traditional 'Oils'"), reference was also made to its relative effectiveness in treating other materials. One stone treated, an amethyst, showed significant improvement in appearance after filling with Opticon. Among the features noted in filled breaks within this stone were blue dispersive colors.

Since that report was published, the editors have treated more than 30 additional faceted quartz gems—rock crystal, amethyst, citrine, and smoky quartz—with Opticon to document its effectiveness further and study identifying features.

In all cases, filled areas had very low relief and could not be detected without magnification. When the stones were examined with a microscope and darkfield illumination, the most prevalent feature was the presence of violetish blue dispersive flashes from the filled breaks (figure 18). On the basis of this investigation, the editors believe that this is the most reliable characteristic for the identification of Opticon-filled fractures in quartz gems.

Figure 18. Violetish blue dispersive flashes, as shown here in an amethyst, are believed to be the most characteristic feature of Opticon-filled fractures in quartz gems. Photomicrograph by John I. Koivula.

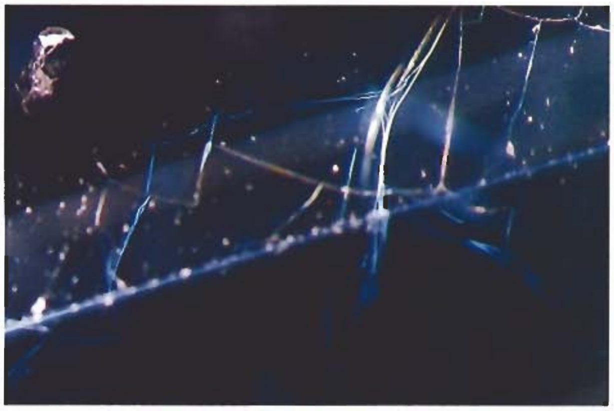


Figure 19. This bale-set emerald crystal has large, cavernous areas that have been "oiled." Photo by Maha Smith.

Filled cavernous emerald crystal. Although substances such as cedarwood oil, Canada balsam, and Opticon are most commonly used to fill fractures in emeralds, occasionally we see them used to fill other openings such as hollow growth tubes and internal cavities with surface-reaching fractures.

Recently, Ron Ringsrud of Constellation Gems, Los Angeles, brought to our attention an unusual bale-set Colombian emerald crystal that had very extensive filled areas. In fact, when we first looked at the stone (figure 19) we thought it might be an assembled specimen, similar to that described in the Summer 1989 Gem News column. Gas bubbles were prominent below the surface in a number of fluid-filled areas extending around the circumference of the crystal. These bubbles could be made to move, showing that they were contained in a fairly fluid substance.

A careful microscopic examination of the crystal revealed its true nature: It is a cavernous crystal, with a solid central core that is almost completely surrounded by hollow, cavernous areas running parallel to the c-axis. The perimeter of the crystal consists only of a thin "shell" of emerald. The filler has an "oily" odor, indicating that the crystal had been treated with one of the more "traditional" filling substances.

Filled synthetic emerald in parcel from Swat. Above, we reported on another incidence of flame-fusion synthetic rubies being encountered in parcels of natural stones from Vietnam. A recent laboratory alert—No. 48, dated November 5, 1991—from the International Colored Gemstone Association (ICA) reports on another variation on this deceptive theme.

The report was submitted by Shyamala Fernandes of the Gem Testing Laboratory of the Gem & Jewellery Export Promotion Council, Jaipur, India. It describes two synthetic emerald cabochons that were discovered in a parcel of stones reportedly from Swat, Pakistan. It was found that one of the two synthetics had been fracture-filled. Dendritic patterns were noted in the filled fractures, which fluoresced a strong yellow to long-wave U.V. radiation.

Deceptive color coating of sapphires in Sri Lanka. Gordon Bleck has also informed the Gem News editors that the demand for yellow sapphires in Sri Lanka has led to widespread heat treatment of appropriate rough. It has also resulted in greater quantities of synthetic yellow sapphire in the local market.

In addition, there has been a resurrection of some "old tricks": surface color coating of rough stones with organic compounds. One method used to mimic the appearance of good-color "golden" sapphire is to boil pale yellow sapphires in water with small branches or the inside bark of a local tree. Sometimes wax is added to the solution to provide a thin outer coating. One method that buyers use to test for this treatment is to immerse the suspect stone in nitric acid, thereby removing any coating present. If wax was used in the mixture, the coating will not be removed unless the acid is first heated.

Pink sapphire rough is also being imitated with a similar coating technique. Pale or colorless crystals are put in the treater's mouth, along with a local berry that is chewed. After a sufficient color coating has been achieved, the treater smokes a cigarette to coat the stone with tobacco residue, which reportedly improves the durability of the color coating.

More on Paraíba tourmaline simulants. With the continued demand for the distinctively colored tourmalines from Paraíba, Brazil, it is not surprising that simulants continue to show up in the marketplace. In the Summer 1990 Gem News column, we mentioned one natural gem that has been marketed as Paraíba material: bluish green to greenish blue apatite from Madagascar.

In September 1991, the ICA released Laboratory Alert No. 47, submitted by Dr. Hermann Bank and Dr. Ulrich Henn of the German Foundation for Gemstone Research (DSEF), which documents a number of these imitators. They, too, mention apatite, and further mention that this material has been found in parcels of rough Paraíba tourmaline. Other Paraíba imitators noted include irradiated topaz that has not been annealed subsequent to irradiation, beryl triplets that consist of two pieces of beryl joined with a bright blue cement, and doublets fabricated from a tourmaline crown and a glass pavilion (figure 20). The last assemblage might be missed without careful microscopic examination, as a refractive index reading taken on the crown would yield R.I. and birefringence values consistent with those of Paraíba tourmaline. Since the publication of the ICA Alert, Dr. Henn has informed the editors that he has seen blue cat's-eye apatites offered as tourmaline cat's-eyes from Paraíba.

Figure 20. A tourmaline crown and a glass pavilion were used to fabricate this assembled imitation of Paraíba tourmaline. Photo courtesy of Dr. Ulrich Henn.

ANNOUNCEMENTS

The Gemmological Association of Australia, in conjunction with the Gemmological Association of Hong Kong, will present a scientific program "Bringing Australian Gemstones to South East Asia" on June 6, 1992, at the Park Hotel, Hong Kong. The event, the GAA's 46th Annual Federal Conference, follows the World Gems and Jewellery Fair being held in that city May 31–June 3. For more information or to register, contact The Gemmological Association of Australia, Federal Chairman, Post Office Box 381, Everton Park, Queensland 4053, Australia.

BOOK Reviews

ELISE B. MISIOROWSKI AND LORETTA LOEB, EDITORS

GEMMOLOGY

*By Peter G. Read, 358 pp., illus., publ. by Butterworth-Heinemann, Oxford, England, 1991. US$65.00**

According to the author, this book resulted from his experience tutoring students who were taking the Gemmological Association of Great Britain's correspondence course, and was developed from the *Beginner's Guide to Gemmology* he published 10 years ago.

His concern for students is evident from the first page, where he begins a discussion of his evaluation of the science of gemology and introduces an excellent section titled "Highlights of the last 150 Years." His opening sentence defines the parameters of the work: "The science of gemmology is concerned with the study of the technical aspects of gemstones and gem materials." With this in mind, the reader can understand why the section on descriptive gemology is relegated to the Appendix and occupies a mere 26 pages in list form unrelieved by any illustrations. The appendix contains good information for the student preparing for the GAGB examinations, in addition to the list of stones for which he will be held accountable.

The author's familiarity with instrumentation is very much in evidence. As each fundamental gemstone property is introduced, he illustrates the various methods and instruments for assessing it. Regrettably, he does not assess the value of each instrument or technique, which suggests that students are on their own in determining whether or not a particular instrument or method is really useful. For instance, this reviewer's experience with the Hartridge reversion spectroscope as a routine testing device was unsatisfactory.

Although there are only four pages of color illustrations, they have been reproduced very well, making the reader wish for more. Unfortunately, some of the black-and-white illustrations leave much to be desired.

An American English speaker is occasionally at a loss to know if something being reviewed is an error or merely the difference expressed in British English, such as *orientated* vs. *oriented*, "aragonite form of calcite," or *nonnucleated* for *tissue nucleated*. However, a few statements that are questionable include: "Only 15% of diamonds fluoresce under long ultraviolet" (in this reviewer's experience, nearly all transparent diamonds fluoresce to some extent); brown and green diamonds are erroneously lumped with the Cape series as having their color due to nitrogen; and the U.S. is mistakenly credited with the manufacture of synthetic amethyst but Japan is not listed.

These are minor faults and hopefully will not mislead an aspiring Fellow. This Fellow wishes that such a book had been available 45 years ago when he was preparing for the exams, although the book makes apparent just how much more there is for today's gemologist to master.

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GEMSTONES AND THEIR ORIGINS

*By Peter C. Keller, 144 pp., illus., publ. by Von Nostrand-Reinhold, New York, 1990. US$49.95**

This is a well-written, attractively packaged, and fascinating account of nine famous gemstone deposits or districts located throughout the world. For each deposit or district, Dr. Keller includes not only a discussion of geology, but also a brief history, the mining methods employed, and a description of important gemstones recovered there. The book is not an encyclopedic account of gemstones or their mineralogy; only a dozen different gem varieties are discussed in some detail, with a few others mentioned only briefly. Instead, it focuses on the geologic origins of gem materials. The book is organized into four parts: (1) gem materials deposited by water on the earth's surface (the gem gravels of Sri Lanka and the opals of Australia); (2) gems of igneous-

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**This book is available for purchase at the GIA Bookstore, 1660 Stewart Street, Santa Monica, CA 90404. Telephone: (800) 421-7250, ext. 282.*

hydrothermal origin (the emerald deposits of Colombia, the gem pegmatites of Minas Gerais, Brazil, and the ruby deposits of Chanthaburi-Trat, Thailand); (3) gems formed at very high temperatures and pressures (the ruby deposits of Mogok, Burma, and the jadeite deposits of Tawmaw, Burma); and (4) gems formed at great depth (the peridot deposits of Zabargad Island, Egypt, and the diamond deposits of Argyle, Western Australia).

Each of the four parts begins with a world map that locates the important gem deposits of each type addressed and a brief summary of the geologic processes thought to be responsible for their formation. These summaries and the nine chapters are written in simple, scientifically correct language that avoids most of the jargon commonly encountered in professional textbooks and scientific papers. Thus, the book should be understood by those with little background in the earth sciences as well as by professional gemologists and geologists. The chapters are an easy-to-read blend, combining well-documented scientific conclusions concerning the geology and origin of each deposit with more popular accounts of the history, gem occurrences, and famous gemstones of that deposit. The presentation benefits from Dr. Keller's personal observations of many of the deposits included in the book. A detailed reference list concludes each chapter, providing both historically important references and more modern studies of each deposit.

Well-designed illustrations are a very important component of the book. Each chapter has excellent color photographs of the deposits and the people who mine them. After reading each chapter, I felt as if I had actually visited the deposit. In addition, the book has clearly drawn geologic or location maps of each gem deposit or district, as well as a number of colored diagrams that are informative (although overly simplified) "cartoons" of the geologic processes responsible for each deposit type. One of the most attractive and appealing aspects of Peter Keller's book is its use of breathtaking color illustrations of mineral specimens, cut and carved gemstones, and jewelry, photographed in large part by Harold and Erica Van Pelt. The placement of illustrations within the text was clearly done with great care, making the contents of the book enjoyable to read and the message easy to understand.

As a professional mineralogist and earth sciences educator, I have had the opportunity to read and study much of the mineralogical literature published during the last 30 years, including many of the more popular writings about mineral deposits. When compared with this large body of literature, I find Peter Keller's book to be a well-written and superbly illustrated introduction to the geologic processes responsible for gem deposits. The price is relatively inexpensive considering the quality of production, paper, and printing. I recommend this book to anyone who enjoys the world of gems and minerals, and particularly to those who wish to learn more about the origin of these fascinating and valuable materials.

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PROFESSIONAL GOLDSMITHING

*By Alan Revere, 226 pp., illus., publ. by Van Nostrand Reinhold, New York, 1991. US$59.95**

In this new book, Alan Revere has created a valuable tool for anyone interested in learning the skill of hand fabricating jewelry. He does a wonderful job of presenting both basic and advanced skills, as well as revealing a few key industry secrets.

The book is well organized into four sections. The first section acts as a good foundation. Fundamentals covered include the most commonly used metals, tools, and basic work procedures.

Section two consists of 16 projects, with a chapter devoted to each. The projects cover a wide range of jewelry, from a basic bracelet and hoop earrings to various types of hand-fabricated chains, rings, and clasps. The layout of the book allows the reader to develop skills and progress from very basic projects such as forging to more complicated ones that require technical soldering skills. The author suggests that beginning students follow the sequence of projects so they learn the necessary skills without becoming frustrated by the more difficult tasks.

Section three consists of 15 more advanced projects which focus on building skill levels by practicing what was learned in previous chapters. These include objects that are more complicated to construct, such as a box clasp, a cluster ring, and a wire brooch.

Each project in the book is presented in clear, easy-to-follow, steps. A brief introduction addresses the skills to be learned, information about the tools needed, and the objective of the project. Over 400 color photos and 64 black-and-white diagrams throughout the book act as progressive visual teaching aids. Charts and tables make up the fourth section of the book. Important reference information provides calculations for determining materials needed and estimating the fineness of an alloy, among other items.

No matter what the reader's skill level or interest in jewelry may be, *Professional Goldsmithing* is a worthwhile investment. It is interesting and enlightening for both the "hands-on" jeweler and the designer who wants to further his or her abilities by understanding how jewelry is constructed.

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GEMOLOGICAL ABSTRACTS

DONA M. DIRLAM, EDITOR

COLORED STONES AND ORGANIC MATERIALS

Akoya pearls at the crossroads? A. Muller, *Swiss Watch & Jewelry Journal Export*, No. 5, May 1991, p. 802.

The members of the Japanese cultured pearl industry voiced alarm about the growing importance of Chinese Akoya pearl production. Their primary concerns include:

- The Chinese Akoya cultured pearl industry will continue to expand rapidly.
- The mediocre quality of Chinese pearls will further depress already threatened global sales of Akoya pearls.
- China's production costs are a fraction of Japan's.
- In the last two years, China's output has risen from some 800,000 mommes (1 momme = 3.75 grams or 18.75 ct) to approximately 1,200,000 mommes, while Japan's own Akoya pearl production has leveled off at around 17,000,000 to 20,000,000.
- China has a healthy mollusk population and more space for breeding grounds than Japan.

All these factors indicate that, if the present trends continue, the Japanese will have to reconsider their current practices and face the prospect of radical changes in their way of doing business.

Jo Ellen Cole

This section is designed to provide as complete a record as practical of the recent literature on gems and gemology. Articles are selected for abstracting solely at the discretion of the section editor and her reviewers, and space limitations may require that we include only those articles that we feel will be of greatest interest to our readership.

Inquiries for reprints of articles abstracted must be addressed to the author or publisher of the original material.

The reviewer of each article is identified by his or her initials at the end of each abstract. Guest reviewers are identified by their full names. Opinions expressed in an abstract belong to the abstracter and in no way reflect the position of Gems & Gemology *or GIA.*

Almandine garnet in Montana sapphire. J. I. Koivula, C. W. Fryer, and R. C. Kammerling, *Zeitschrift der Deutschen Gemmologischen Gesellschaft*, Vol. 40, No. 2, 1991, pp. 89-92.

This article details an almandine garnet inclusion found in a 3.55-ct rough sapphire crystal from the Dry Cottonwood Creek area in Montana.

The Dry Cottonwood Creek alluvial deposit was discovered in 1889, several years before the Yogo Gulch deposit. Its sapphires apparently crystallized in an igneous environment. Crystals commonly display etched surfaces on tabular forms or a water-worn appearance.

The inclusion described is slightly brownish orange and isotropic in nature, measuring approximately 0.8 mm in diameter. It was first thought to be a spessartite garnet due to its color and transparency. However, microspectroscopy and X-ray powder diffraction proved that it was an almandine, although some spessartine component may be present. The major component determines the species, so this garnet was identified as almandine. *Jo Ellen Cole*

Australia's magnificent pearls. D. Doubilet, *National Geographic*, Vol. 180, No. 6, 1991, pp. 108-123.

Doubilet's text on pearl farming in Australia ricochets from farm to farm across the northern coast of Australia, jumping back and forth from factual descriptions of pearls and pearling to a sort of lyrical adventurama that tells the once and present problems that face the hopeful farmer. Accompanied by a superb photographic essay, this article details the hazards of the deep, the tedium of tending the "seeded" mollusks, and the fulfillment of the dream. Diving is a major part of the drama, since *Pinctada maxima*, the mollusks used to culture the pearls, are gathered full grown from the ocean floor. These mollusks are then nucleated and tended through at least one, but possibly several, harvests.

In Australia, pearling is a closed society in which the pearlers keep a tight control on production in order to prevent the overfishing that could wipe out the mollusk beds essential to the industry. Although most cultured pearls still come from Japan, Australian farms produce 60% to 70% of the world's supply of South Sea pearls. *Archie Curtis*

Gemmology Study Club lab reports. G. Brown, S. M. B. Kelly, and R. Beattie, *Australian Gemmologist*, Vol. 17, No. 9, 1991, pp. 363-367.

The first material covered is an apparently new imitation of jadeite being sold in the Orient. The carved pieces are both dyed and wax-coated, and consist of a grayish green, feldspar- and mica-rich rock that is mined on the Philippine island of Mindanao and known locally as "Philippino [sic] jade." Next, the authors report the presence of elongated gas bubbles in the diffusion layer of so-called "deep" diffusion-treated sapphires.

An entry on an 18.9-ct faceted cerussite includes useful tips on how to fashion this fragile collector's gem. This is followed by reports on two organic gem materials: the claws (dactyls) of the Philippine mantis prawn (pictured here set in earrings) and cultured blister pearls of the small *Pinctada maculata* oyster from the Cook Islands. A helpful note on the identification of bone follows. A final entry on red Kauri gum includes information on material recovered from coal seams as much as 40 million years old. This fossil Kauri gum reportedly has properties identical to those of amber and, furthermore, cannot be distinguished from amber on the basis of solubility to volatile solvents such as ether or chloroform. *RCK*

The mystery of the missing mollusks. D. Haldane, *Los Angeles Times Magazine*, January 5, 1992, pp. 23-26.

This brief, detailed article concerns the endangerment of the abalone that can (rarely, now) be found along the California coastline, especially around Anacapa Island. The abalone are prized for their meat as well as for their colorful shell (also referred to as Paua shell), which is incorporated in jewelry and other decorative items. As a result of overfishing, pollution, the growing numbers of sea otters (a predator), and a mysterious disease that is killing the abalone, the mollusk population in this area has dropped more than 90% in the last 30 years. Conservation programs are being instituted to save the abalone and preserve their habitat. Three color photographs illustrate the article. *RT*

Rhino horn and elephant ivory. N. F. Singer, *Arts of Asia*, Vol. 21, No. 5, 1991, pp. 98-105.

Elephant ivory and rhinoceros horn have been associated with the arts of China and Myanmar (Burma) for 3,500 years; in this well-researched but disorganized article, the author discusses the use of these materials by artisans, magicians, and the military.

To the lay reader, the article is interesting primarily for its environmental focus. By the year 1,000 AD, overhunting had led to the near-disappearance of both animals from China. Contemporary writers predicted the elephant's extinction and bemoaned the frivolous use of ivory by "courtesans and the nouveau riche." Military demand for the skins of both animals added pressure to the shrinking populations.

The Chinese belief in rhinoceros horn's aphrodisiac qualities is well known. The Myanmar valued the beast for its ability to neutralize poison.

By the end of the 16th century, Chinese elephants were seen only in the Imperial stables, and ivory carvers were supplied with African tusks by Spanish and Portuguese traders. This continued trade has led, of course, to the near-extinction of both animals in this century. *Lisa E. Schoening*

DIAMONDS

India's diamond crisis worsens. J. Shor, *Jewelers' Circular-Keystone,* Vol. 162, No. 8, August 1991, pp. 160-162.

India's diamond business may not be as strong as it appeared several years ago. This article discusses and explains the financial problems of diamond dealers in India, many of whom have had difficulties paying for their sights.

Sight allocations have been suspended to those Indians who have not paid for previous sights, in large part because the Reserve Bank of India has put restrictions on the conversions of rupees to the currency needed for international transactions.

India's currency problem began during the Persian Gulf crisis, when the government ran low on foreign exchange. The country's chief source of foreign currency had been the thousands of Indian expatriate workers in the Persian Gulf, who accounted for more than one billion U.S. dollars a year. However, these workers were forced home after Iraq invaded Kuwait. As a result, the diamond-polishing force has already dropped from 800,000 to about 500,000. While many dealers predict improvements in the future, in the short term diamond exports will continue to decline.

KBS

When diamonds met buckyballs. A. S. Moffat, *Science,* Vol. 254, No. 5033, November 8, 1991, p. 800.

Science magazine voted synthetic diamond films "Molecule of the Year" for 1990 because their potential practical applications are so great. However, a major problem has continued to be finding a suitable base on which to grow the material. A pretreated coating of synthetic diamond grit is impractical in many cases, and alternatives such as pump oil or various compounds of hydrocarbons fail because they lack both stability at high temperatures and the three-dimensional cage structure required for the growth of diamond's molecular structure.

Now, researchers R. P. H. Chang and Manfred Kappes of Northwestern University have found that synthetic diamond films easily grow on coatings of C_{70} clusters. These are relatives of the original C_{60} "buckyball," named after physics genius Buckminster Fuller, best known as father of the geodesic dome. Chemically inert resilient compounds, these hybrids of the C_{60} buckyballs were deposited on a surface and bombarded with carbon and hydrogen ions, breaking open the cage structure and exposing the free ends of the buckyballs' carbon network. This provides an ideal template for nucleating diamond growth. The researchers found that a base layer of C_{70} molecules was about 10 orders of magnitude better at seeding diamond-film growth than an untreated surface. *Jo Ellen Cole*

GEM LOCALITIES

Some Australian turquoise deposits. G. Brown, *Australian Gemmologist,* Vol. 17, No. 9, 1991, pp. 369-373.

Turquoise has been found in all Australian states with the exception of Western Australia. This report begins with a general description of the chemistry, formation, and gemology of turquoise and then focuses on three significant Australian sources.

The Bodalla-Narooma turquoise deposits are found on the southern coast of New South Wales. The Bodalla field, discovered in 1894, was the first turquoise deposit in Australia to be commercially mined. The Tosca mine, near Ammaroo Station in the Northern Territory, currently supplies large quantities of porous material to cutters in both Southeast Asia and Germany. The third locality discussed, at the Iron Monarch sedimentary iron ore deposit in South Australia, is significant for its rare, near-microscopic turquoise crystals.

This useful locality report includes a table of generalized gemological properties of turquoise, plus some specifics relating to the deposits discussed. A second table succinctly lists (with references) the several Australian turquoise deposits. *RCK*

INSTRUMENTS AND TECHNIQUES

Application of mineralogical techniques to gemmology. C. M. Gramaccioli, *European Journal of Mineralogy,* Vol. 3, No. 4, 1991, pp. 703-706.

Mr. Gramaccioli feels that the jewelry trade is coming out of the age of inbred apprenticeships to absorb scientific concepts at a surprising rate. A concurrent tendency to improve scientific equipment in gemological laboratories is motivated by four factors:

1. The increasing demand for "written guarantees" for gemstones
2. The wide variety of gem and, especially, synthetic gem materials available
3. The need to cut stones along the appropriate crystallographic orientation
4. The effort to improve identification methods for synthetic and treated gemstones

The author points out the need not only for sophisticated scientific instrumentation, but also for proper scientific education of the operator and of the members of the gem trade at large. This should be done in collaboration with scientific institutions, which will also derive benefits from working on gemological materials.

The role of X-ray crystallography is explained at length, together with recent experiments done in the author's laboratory. Chemical analyses still present some challenges (proper mounting, analysis of light elements such as boron), which will probably be overcome in time. Raman, infrared, and optical absorption spectroscopy are also very useful to the gemologist.

One feels throughout the article that the author, although full of laudable intentions, has little knowledge of, or concern for, the very practical needs of the jewelry industry. This article lacks examples that show the practical value of gemological research. Also, the absence of any mention of X-ray fluorescence as a useful technique, and the inference that some gemological laboratories have an electron microprobe on their premises (which to this abstracter's knowledge is not the case), certainly promotes a skewed picture of the reality of gemological research. *EF*

The Gold-Meter®. T. Linton and G. Brown, *Australian Gemmologist,* Vol. 17, No. 9, 1991, pp. 360-362.

The Gold-Meter® is an electronic instrument that uses an electrochemical process to test the precious metal content of jewelry. Its two major components are a micro-computer and a handheld testing pen, the latter holding a reservoir of an acid testing solution.

According to this Instrument Evaluation Committee report, the Gold-Meter® is easy to use and accurate for calculating gold content to the nearest karat for alloys in the 6-18 K range. For alloys between 18 and 24 K, the instrument simply identifies the metal as being within this rather broad range. Other limitations relate to the different types of gold alloys—e.g., pink, white, and green golds—where a conversion table (provided) and some interpretation of results is required. It is important to note that, as with other portable gold-testing units, the pen's acid produces a brownish stain on the metal at the point of testing. This must be removed with gentle abrasion and repolishing. *RCK*

Lasers in the jewelry trade. W. M. Steen, *Goldsmith's Technical Digest,* 1990/91, pp. 10-15.

This article covers the current uses and the future of the laser in the creation, decoration, and repair of jewelry. With the assistance of a computer-aided design (CAD) package, lasers can be involved in making molds for lost-wax casting. The laser (Light Amplification by the Stimulated Emission of Radiation) has the ability to focus a beam of light to a very fine point, which allows the operator to work on a small area without affecting the surrounding area. This is particularly useful for enameling, electroplating, fusion welding, and soldering. Possible future applications include engraving and carving. One table included in this article provides a breakdown of the different types of lasers used for metal work. *RT*

Radioactivity of some minerals in the Mogok area. U.T. Hlaing, Z. Aung, and W. Htein, *Australian Gemmologist,* Vol. 17, No. 9, 1991, pp. 356-359.

This article reports on radioactivity measurements carried out on zircon, apatite, and sphenes from Myanmar (Burma). Uranium and thorium contents were measured using high-resolution gamma spectrometry with a high-purity germanium (HPGe) detector and by the radioisotope-excited X-ray fluorescence method (XRF).

The authors obtained the following results: (1) the zircon contained more uranium—150 to 2,200 ppm, with an average value of 681 ppm—than either the sphene or apatite, with apatite showing the lowest uranium content; (2) the sphene contained 110 ppm thorium, but the thorium contents of the zircon and apatite were below the minimum detection limit for the XRF method; and (3) in all cases, the uranium content was higher than the thorium content. Unfortunately, the correlation between the gamma-ray spectroscopy and XRF was extremely poor, with the difference in readings varying from less than 1% to more than 300%.

The zirconium/hafnium ratio was also calculated for the zircon and was found to be different from that reported for zircon from other localities. This and other data suggest that Myanmar zircon is of granitic origin. *RCK*

Des techniques qui déconcertent les meilleurs experts: Au royaume des pierres le faux vrai et le vrai faux (Disconcerting techniques even for the experts: In the stone kingdom, the false true and the true fake). J.-L. Mothias, *Le Figaro,* October 12-13, 1991, p. 8.

This newspaper article describes how French experts feel that even sophisticated techniques are sometimes not enough to help with difficult gem identification problems. One such example is the separation of natural-color from treated-color green diamonds. Large amounts of colorless topaz and diamonds are irradiated in Delft, The Netherlands, and in San Diego, California, to produce a more salable color. This color is very difficult to identify as resulting from laboratory treatment. One expert from the laboratory of the Paris Chamber of Commerce is cited as saying that, in difficult cases, the expert gemologist can only rely on experience. The article is illustrated with a picture of the Charlemagne talisman. A lengthy caption explains that the central cabochon was called a blue glass fake by Fred Ward in a recent *National Geographic* article, although the museum's description of the jewel actually states that one of the original cabochons was replaced with a larger piece of blue glass.

It is unusual to see articles that explain the difficult challenges of gem identification to the widest possible audience, i.e., that of a nationwide newspaper. It means also that, in France at least, there is a general feeling that synthetics and treatments are so sophisticated that in some cases they cannot be identified, although they were fairly easy to detect in the past.

EF

JEWELRY MANUFACTURING ARTS

Ancient jewellery: A conservator's eye view. M. Hockey, *Goldsmith's Technical Digest,* 1990/91, pp. 16-21.

The aim of conservation for ancient jewelry is to restore and preserve the object so that it can be displayed and handled for academic study. The author, senior conservator in the Department of Conservation at the British Museum, provides a brief history of jewelry, with the earliest examples of bone, shell, and teeth used for beads dating back 30,000 years. She succinctly discusses chemical deterioration and the restoration of gold, silver, copper, enamels, glass, and gemstones. Specific examples are discussed in the article, accompanied by 10 color photographs.

RT

Der wille zum experiment (The will to experiment). S. Lambert, *Art Aurea,* No. 1, 1991, pp. 59-61.

Gold takes on many forms in the work of the designers represented at the recent "Triennale Europeene du Bijoux Contemporain" in Luxembourg. Treasured since prehistoric times, gold's versatility and sensual appeal is displacing aluminum and space-age metals (which not long ago dominated Europe's industry-inspired creations) in these thoroughly contemporary works.

The show's purpose was to convey the actual state of the art of creating jewelry; 300 artists representing the Japan Jewelry Designer Association and the World Gold Council participated. Although the jewelry displayed owes more to art than to commercial instinct, some of the design concepts will certainly be seen at trade shows within the next few years.

This well-illustrated article is printed in both German and English. *Lisa E. Schoening*

JEWELRY RETAILING

The bracelet's charm. B. L. Scherer, *Town & Country,* Vol. 145, No. 5139, December 1991, pp. 174-177, 217-218.

Mr. Scherer presents a concise history of the bracelet in this compact but meaty article, accompanied by 17 beautiful photographs by Matthew Klein.

The oldest evidence of bracelets has been found in excavations and cave paintings of the Paleolithic period. The earliest reference in English dates to the 1438 inventory of King James III of Scotland. The author also discusses several historical paintings and sculptures in which bracelets are featured, as well as the importance of bracelets in imperial regalia. He then reviews a number of collections of recent well-known personalities, from Gloria Swanson to Andy Warhol.

Neo-Etruscan Victorian bangles, 1920s and 1930s platinum pieces, and second-hand contemporary bracelets by design houses such as David Webb, Cartier, and Tiffany continue to be very popular among collectors of estate jewelry. Trends in modern bracelet wear are discussed, with emphasis on wider metal bangles for daywear and narrower, stone-set, flexible bracelets for formal evening attire.

Scherer concludes this fascinating article by stressing how important it is to pay attention to detail, such as the quality of construction and finishing of prongs, when purchasing bracelets. This attention to detail is equally important in caring for your bracelet once it has been purchased. *Jo Ellen Cole*

Crime against jewelers. G. Holmes, *Jewelers' Circular-Keystone,* Vol. 162, No. 9, September 1991, pp. 40-65.

This special report is devoted to the increasing problem of crime in the jewelry industry. Mr. Holmes goes into great depth on how to help prevent burglaries in a business, with 20 tips to deter robberies. He emphasizes using common sense when it comes to security—before, during, and after a holdup. He discusses insurance policies and how to handle adjusters when purchasing insurance for your store, as well as after you have been robbed. Equipment that should be used to help discourage burglars includes surveillance cameras, buzz-in locks, and mirrors. Perhaps most important is the description of trade associations such as the Jewelers Security Alliance and Jewelers Mutual Insurance, which are a greatly under-used security tool. Holmes includes in his discussion accounts of 29 actual crimes. *KBS*

The personal computer: A jeweler's tool. M. Golding, *Jewelers' Circular-Keystone,* Vol. 162, No. 12, December 1991, pp. 52-56.

Michael Golding gives a detailed account of the advantages of computerizing one's business. He divides these advantages into four basic functions: accounting, inventory, receivables, and payables. Then he presents specific examples, such as how to save on accounting costs and how a computer can help with mailing lists, appraisals, jewelry design, bench-ticket scheduling, etc. He also discusses what the computer cannot do—such as substitute for people or transform a business overnight. This article is a useful incentive for those who would like to computerize their business. *KBS*

Preserving history at top jewelry houses. V. Swift, *Jewelers' Circular-Keystone,* Vol. 162, No. 8, August 1991, pp. 174-182.

Our present "information age" has underscored the importance of preserving and documenting records that have potential historic significance. Many of the large jewelry houses have archivists who collect, catalogue, and preserve the artistic traditions of their companies. Items that are archived range from design renderings to the jewels themselves, the latter frequently repurchased by the company at international auctions.

Three of the legendary jewelry houses—Tiffany, Cartier, and Van Cleef & Arpels—are the focus of this interesting article. Interviews with the archivists for Cartier, and with Nina Wohl at VC&A, give us an understanding of the fascinating variety of information that can be found in these archives, as well as the amount of work that goes into amassing them. Although much of the work is tedious and difficult, the results are rewarding and of value to all within the jewelry community. This article proves, once again, that there is much to learn from our past. *EBM*

Editor's Note: GIA's Liddicoat Gemological Library and Information Center is prepared to be the archival repository for records from other companies in the jewelry industry. Contact Dona Dirlam at GIA Santa Monica for further information.

What every jeweler should know about appraisals. S. W. Ipsen, *Jewelers' Circular-Keystone,* Vol. 162, No. 8, August 1991, pp. 192-198.

Writing appraisals for jewelry in today's sophisticated world is no easy task, although many jewelers are not yet aware of this fact. Gone are the days when "one gold and diamond ring, value $2,000" would be considered an appraisal. This article emphasizes the seriousness of performing appraisals, which are legal documents used by insurance companies, police departments, and banks, as well as in the settlement of property following divorce or death.

The author, Sylvia Ipsen, indicates the many details that should be included in a jewelry appraisal, and covers some basic points that all appraisals have in common. She also instructs the potential appraiser to seek further assistance from one of the nation's appraisal organizations, which will "provide help to qualified individuals in preparing acceptable appraisals." Lastly, Ms. Ipsen underscores the fact that appraisals are not easy to prepare and can have unpleasant legal repercussions if not prepared correctly. *EBM*

SYNTHETICS AND SIMULANTS

Synthetic found mixed with rough ruby. *Jewellery News Asia,* No. 85, September 1991, p. 172.

Rough synthetic ruby has recently been found mixed in parcels with good-quality natural rough that was being sold in China, Thailand, and Vietnam. The Hong Kong Gems Laboratory has found that approximately 30% of the rubies tested from these parcels were flame-fusion synthetics. The synthetics are being tumbled to give them the appearance of rough mined from a secondary source. In addition, some have been found to have cracks caused by heating and rapid cooling. The cracks are similar to those seen in some natural rubies. *Jana E. Miyahira*

Editor's Note: A photo of "rough" synthetic ruby purchased in Vietnam as natural ruby appears in the Gem News section of this issue of Gems & Gemology.

Verneuil synthetic red spinel. G. Brown, R. Beattie, and J. Snow, *Australian Gemmologist,* Vol. 17, No. 9, 1991, pp. 344-347.

Following a well-referenced review of the development of Verneuil synthetic spinel, focused on red material, the authors describe their investigation of some red synthetic spinel boule fragments and faceted stones. The material, purchased at the 1987 Tucson Gem Show, had the following gemological properties: color—bright, slightly purplish red; diaphaneity—transparent; luster—vitreous; polariscope reaction—minimal anomalous double refraction; S.G.—3.59; U.V. fluorescence—bright red (long-wave) and inert (short-wave); absorption spectrum—broad, strong absorption from 500 to 580 nm and strong general absorption below 465 nm. In addition, an emission band centered at 685 nm was noted in the spectroscope when the stone was stimulated with long-wave U.V. radiation.

Magnification revealed broad curved color banding, as well as single-phase (gas bubble) and two-phase (gas bubble plus a solid or liquid phase) inclusions oriented in lines perpendicular to the curved growth. The gas bubbles were quite variable in shape, including rounded, tadpole-shaped, and elongated, highly convoluted types.

The authors conclude that, because all gemological properties of this material overlap with those of natural spinel, standard testing procedures—with the exception of microscopic features—cannot be used to distinguish this synthetic spinel from its natural counterpart. *RCK*

TREATMENTS

Examination of a plastic coated "sugar-treated" opal. R. C. Kammerling and J. Koivula, *Australian Gemmologist,* Vol. 17, No. 9, 1991, pp. 352-355.

The authors received an unusual opal that was purchased for a considerable sum in Australia as a "black opal." Without magnification, the opal appeared to have an even, black body color, against which it displayed a fairly strong, uniform "pinfire" play-of-color. Examination through a binocular microscope revealed the "peppery," speckled appearance associated with sugar-treated opal from Australia. A colorless coating covered the entire cabochon; it was significantly thicker at the base than on the dome, and contained gas bubbles. The coating appeared orange when examined in transmitted light.

After various gemological tests, the authors concluded that the specimen was a natural opal that had been "sugar treated" and subsequently plastic coated, possibly to "set" the initial treatment as well as protect the surface and improve the apparent polish.

Maha Smith

MISCELLANEOUS

The mineral collection of Moritz and Adolf Lechner, Vienna. B. Smith, *Mineralogical Record,* Vol. 22, No. 6, 1991, pp. 433-438.

This essay recounts the dispersal of the Lechner mineral collection, once one of Europe's largest and finest private mineral collections. The collection was formed by Moritz Lechner in Vienna during the late 1800s. It was left to his son, Dr. Adolf Lechner, who continued to add specimens. The Lechner collection grew primarily by the purchase of all or part of existing respectable European collections; a list of some of these early collectors accompanies the article.

The collection ultimately consisted of 8,314 specimens; the majority ranged from 4 × 6 cm to 8 × 10 cm. Most of the mineral species considered valid in the early 20th century were represented, along with specimens from Central European localities and silver ore minerals. In 1911, the entire collection was offered for sale. It remained intact and available for more than 40 years, before it was ultimately dispersed to American museums and private collectors. In 1952, approximately half of the specimens were sold to Raymond and Alvin Schortmann, from whom both Harvard University and the Smithsonian Institution purchased some in 1955. The Smithsonian's original 355 Lechner specimens were incorporated into the Roebling collection. In 1959, they purchased 249 additional Lechner specimens from the Schortmanns.

By the early 1960s, the remaining Lechner specimens were released for sale to the general public. In 1971, Ron Bentley purchased the Schortmanns' business, including those Schortmann/ Lechner specimens that had not yet sold. The author suggests that 3,000 Lechner specimens have been sold directly to U.S. collectors.

The 10 color photographs that accompany this article include specimens of gem materials such as garnet, cassiterite, prehnite, and lazulite.

LBL

More "PERFECT" Challengers

Following are the names of "Perfect Challengers" who were inadvertently left out of the list printed in the Fall 1991 issue. All received a perfect score on the 1990 *Gems & Gemology* "Challenge."

Michael J.P. Cavanagh, Vancouver, B.C., Canada; Raffi M. Eurdekian, Southfield, MI; Jim Ferguson, North Charleston, SC; Agop Ghazalian, Santa Ana, CA; Edward D. Gold, Hemet, CA; Martin D. Haske, Woburn, MA; Werner R. Hoehne, San Francisco, CA; Rhonda R. Jones, Vancouver, B.C., Canada; Gary Ephraim Kampel, San Mateo, CA; Dorothy Lewis, Richboro, PA; Lianne Lui, San Jose, CA; Cheryl Ann Lundstrom, Concord, CA; Kathryn J. March, Winston Salem, NC; Kathleen J. Molter, Milwaukee, WI; Richard Petrovic, Newport, OR; Pinchas Schechter, Miami Beach, FL; Nancy Marie Spencer, Corona, CA; Larry C. Winn, Arvada, CA.

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SUBJECT INDEX

This index gives the first author (in parentheses) and *first page* of the article in which the indexed subject occurs, as well as the precise page in the Gem Trade Lab Notes (GTLN), Gem News (GN), and Editorial Forum (EF) sections. The reader is referred to the author index for the full title and the coauthors, where appropriate, of the articles cited.

Indexes prepared by Dona Dirlam and Carol Stockton

AUTHOR INDEX

This index lists, in alphabetical order, the names of authors of all articles that appeared in the four issues of Volume 27 of *Gems & Gemology*, together with the inclusive page numbers and the specific issue (in parentheses). Full citation is provided under the first authors only, with reference made from joint authors.

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Gems & Gemology is an international publication of original contributions concerning the study of gemstones and research in gemology and related fields. Topics covered include (but are not limited to) colored stones, diamonds, gem instruments and identification techniques, gem localities, gem enhancements, gem substitutes (simulants and synthetics), gemstones for the collector, jewelry manufacturing arts, jewelry history, and contemporary trends in the trade. Manuscripts may be submitted as:

Original Contributions—full-length articles describing previously unpublished studies and laboratory or field research. Such articles should be no longer than 6,000 words (24 double-spaced, typewritten pages) plus tables and illustrations.

Gemology in Review—comprehensive reviews of topics in the field. A maximum of 8,000 words (32 double-spaced, typewritten pages) is recommended.

Notes & New Techniques—brief preliminary communications of recent discoveries or developments in gemology and related fields (e.g., new instruments and instrumentation techniques, gem minerals for the collector, and lapidary techniques or new uses for old techniques). Articles for this section should be approximately 1,000-3,000 words (4-12 double-spaced pages).

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All material, including tables, legends, and references, should be typed double spaced on 8 1/2 × 11" (21 × 28 cm) sheets with 1 1/2" (3.8 cm) margins. It is preferable, but not essential, that the article be submitted (preferably in Microsoft Word or in ASCII format) on an IBM-compatible floppy disk (either 3 1/2" or 5 1/4") as well as in hard copy form. Please identify the authors on the title page only, not in the body of the manuscript or figures, so that author anonymity may be maintained with reviewers (the title page is removed before the manuscript is sent out for review). The various components of the manuscript should be prepared and arranged as follows:

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Armstrong J.T. (1988) Accurate quantitative analysis of oxygen and nitrogen with a Si/W multilayer crystal. In D. E. Newbury, Ed., *Microbeam Analysis—1988*, San Francisco Press, San Francisco, CA, pp. 301–304.

Liddicoat R.T. (1989) *Handbook of Gem Identification*, 12th ed., 2nd rev. printing. Gemological Institute of America, Santa Monica, CA.

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