KILBOURNE HOLE PERIDOT

By John R. Fuhrbach

This little-known source of gem-quality peridot, located in southwestern New Mexico, produces small but brilliant gems. Kilbourne Hole peridot is found in the explosion debris of a 180,000-year-old volcano, usually in elliptical "xenolith bombs." Kilbourne Hole peridot has a greater color range than the San Carlos, Arizona, material and an additional characteristic inclusion. Although the deposit is not being mined commercially, thousands of carats of gem-quality peridot have been found there.

ABOUT THE AUTHOR

Mr. Fuhrbach is a gemologist and retail jeweler in Amarillo, Texas, who specializes in unique gemstones and jewelry.

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The use of peridot as a gem dates to 1500 B.C., when it was mined by Egyptian slaves on the island of Zabargad, off the Egyptian coast. The Egyptians knew the prized material by its Greek name *topazion* (allegedly from the Greek verb "to seek," because the island source was often enveloped in mist; Gübelin, 1975). In 1790, mineralogist A.G. Werner named the typically green mineral *olivine*, after the Latin for "olive."

Today, the mineral is still referred to by geologists and mineralogists as olivine, but by gemologists as peridot—a French name adapted from the Arabic *faradat*, meaning "gemstone" (Gübelin, 1981). Composition varies along a solid-solution series between forsterite and fayalite, but most single-crystal material falls within the range of 70%–90% forsterite.

Peridot occurs virtually worldwide and perhaps throughout the universe. The most notable gem deposits are found in Myanmar (formerly Burma, which furnishes the largest cut gems) and Arizona, but other noteworthy localities are in Antarctica, Australia, Brazil, China, Finland, Germany, Hawaii, Italy, Kenya, Mexico, New Caledonia, Norway, and Russia (see, e.g., Arem, 1987). In addition, peridot was found on the moon by the crews of Apollo 11 and Apollo 12, and has repeatedly been encountered in meteorites (pallasites).

One of the lesser-known deposits is Kilbourne Hole, New Mexico, which was briefly described by Lindberg (1975) and mentioned by Shaub and Shaub (1975) but has not otherwise been investigated in the literature. Although well-formed single crystals have not been found at Kilbourne, several fragments as large as 33 ct and several nodules with areas of cuttable peridot as large as 128 ct have been examined and cut by the author (figure 1).

LOCATION AND ACCESS

Kilbourne Hole is a late Pleistocene (approximately 180,000 years old; Seager et al., 1984) volcanic crater (figure 2) located

Figure 1. Kilbourne Hole, New Mexico, is one of the least studied and yet most interesting of the known localities for gem-quality peridot. This 9.58-ct Kilbourne Hole peridot, surrounded by diamonds, is set in an 18k gold ring designed by the author. Photo © Harold & Erica Van Pelt.

about 32 km (20 mi.) southwest of Las Cruces, New Mexico, and only about 20 km (12.5 mi.) north of the U.S. border with Mexico (figure 3). Access to the deposit can be determined by following U.S. Geological Survey maps from the towns of Afton, New Mexico, or El Paso, Texas. The roads may be hazardous, often with high clearances and deep sand, so a four-wheel-drive all-terrain vehicle should be used.

The altitude varies from 1,284 m (4,212 ft.) on the southern rim of the maar to 1,330 m (4,362 ft.) at the top of the eastern sand dunes and ridges, and drops some 134 m (438 ft.) from the eastern rim of the caldera to the bottom of the caldera dry lake. For several kilometers around, the area consists of desert sparsely vegetated with yucca and bush mesquite (again, see figure 2). Typical daytime temperatures in early July are approximately 47°C (117°F) at the rim and 53°C (127°F) on the dry-lake bottom, with humidity of only 1%. What little rainfall there is occurs during the last weeks of August. Thus, water is nonexistent and visitors must bring their own.

Because of the intense heat most of the year, prospecting and/or camping is recommended only from late November through February. Even then, five varieties of poisonous desert rattlesnakes inhabit the region; familiarity with desert survival is essential for camping in the area. Most of the land is under government supervision, and access is unrestricted; the approximately one-third of the northeast section that is on private land is fenced off.

GEOLOGY AND OCCURRENCE

The elliptical Kilbourne Hole is approximately 3.2 km long × 2.2 km wide. It is classified as a maar (a crater formed by violent explosion without igneous extrusion) and resembles other maars found in Germany, India, Mexico, and elsewhere in New Mexico (Seager, 1987). Except to the south, it is surrounded by a prominent rim of ejecta (material thrown out of an active volcano), that is as much as 46 m above the La Mesa plains and up to 107 m above the crater floor. The outer walls of the rim have gentle slopes; the inner walls are steep to vertical.

The precrater rocks belong to the early to middle Pleistocene Camp Rice formation (Gile et al., 1981) overlain by the Afton basalt (again, see figure 3). Over

Figure 2. Kilbourne Hole is an extinct volcano, approximately 7 km² in area. Gem-quality peridot is found scattered throughout the area, having weathered out of the tuff-ring ejecta that form the walls of the crater. The terrain in this extremely dry area is barren, occupied primarily by bush mesquite, yucca, and rattlesnakes.

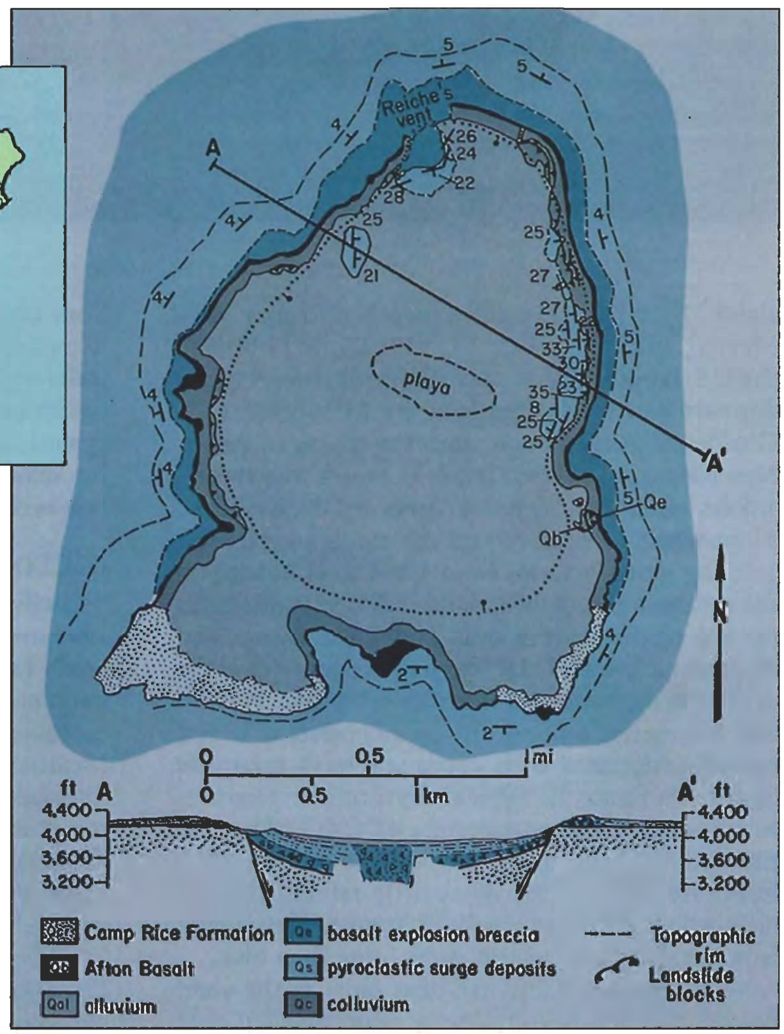


Figure 3. Kilbourne Hole lies in Doña Ana County, New Mexico, close to the border with Mexico. The geologic map not only delineates the rim of the crater but also the various units that comprise the crater and the rim. The peridot-containing "xenolith bombs" have been found in situ *primarily in Qe, the basalt explosion breccia; only a few have been found in the pyroclastic surge deposits, the upper unit of the tuff-ring ejecta. Geologic map by W. R. Seager, New Mexico State University.*

these rocks lie the tuff-ring ejecta deposits, from the explosion phase of the crater's formation, which form the rim, back slopes, and upper half of the crater wall (again, see figure 2). The lower portion of the tuff-ring ejecta is absent in some areas and up to 50 m thick in others. It is a breccia that consists of angular blocks of Afton basalt in a matrix of unstratified pyroclastic fall deposits, including mantle and lower-to-upper crustal "xenolith bombs" (Reiche, 1940). The upper part of the tuff-ring ejecta consists of much finer grained stratified pyroclastic-surge and pyroclastic-fall deposits up to 35 m (about 115 ft.) thick on the east rim (Shoemaker, 1957; Hoffer, 1976; Brenner, 1979; Stuart and Brenner, 1979; Stuart, 1981).

The peridot is an early crystallization, formed during the solidification of igneous rocks from the liquid magmatic phase (Northrop, 1959; Gübelin, 1975). Essentially, when the volcano erupted, it threw liquid magma into the atmosphere. As portions of the magma spun through the air, their outer surfaces cooled first, retaining an elliptical shape due to the spinning action. This outer crust acted as insulation, allowing the molten interior enough time to cool that crystals could form. Thus, peridot is found with augite and diopside (and occasionally enstatite and bronzite) inside these basalt-coated "xenolith bombs" (figure 4), which may be as large as 25 cm (about 10 in.) in diameter (Lindberg, 1974), and as fragments (figure 5) lying on the ground. The "bombs" appear *in situ* only in the tuff-ring ejecta, most commonly in the lower portion. Eons of weathering have exposed these potato-shaped masses and left thousands lying on the ground above the caldera rim. The author and his wife recovered more than 1,433 ct of facetable material in only five days, entirely by handpicking "bombs" and fragments from the surface; several visits have yielded a total "production" of some 4,000 ct of cuttable peridot. However, there is no evidence in the literature or at the locality that Kilbourne Hole has ever been formally mined.

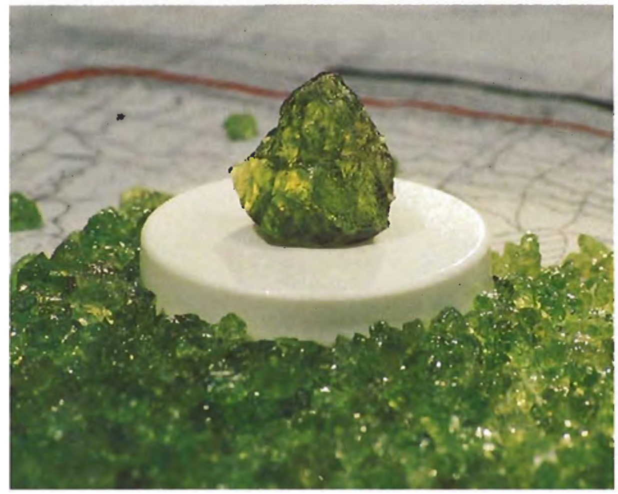


Figure 5. Fragmentary pieces of peridot, much of it facet grade, are also found lying on the ground at Kilbourne Hole. The large "fragment" in the center here weighs 33 ct; most of the pieces that surround it are small (less than 2 ct) but of good color and clarity.

Figure 4. Basalt-coated "xenolith bombs," like the one shown here, often contain gem-quality peridot. They can be picked up off the surface, where they have weathered out of the surrounding tuff ring. A sharp tap with a hammer will break open the "bomb" and reveal any gem material inside.

MATERIALS AND METHODS

A study collection of 1,026 rough samples (total weight approximately 610 ct) and 21 faceted stones (total weight 54.24 ct) was divided initially into four color groups, designated KH1, KH2, KH3, and KH4; KH2 and KH3 were subsequently combined. Gemological properties were taken on a subset of 146 representative samples.

Refractive indices were determined with a Rayner refractometer and high-intensity sodium-vapor lamp. Pleochroism was determined with a GIA-GEM polariscope, Rayner and GIA calcite dichroscopes, and a Bausch & Lomb petrographic microscope. Specific gravities were taken hydrostatically using stabilized 1,2-dibromomethane and a Christian Becker analytical balance. Ultraviolet testing was done with high-intensity (100W), filtered, mercury-vapor lamps at

Figure 6. Evidence of peridot can be seen along the broken portions of these basalt-coated xenolith "bombs." These nodules range from 7 × 5.5 × 4 cm (0.25 kg) to 23 × 23 × 19 cm (15.9 kg). The largest "bombs" generally do not produce the largest facetable material.

typical short (253.7 nm) and long (366.0 nm) wavelengths.

Optical spectra were observed under darkroom conditions with two desk-top spectroscope units, one with a Beck prism spectroscope and the other with a GIA-GEM digital-readout, scanning, diffraction-grating spectroscope. Optical and infrared spectroscopy were also performed for eight samples—one tablet and one faceted gem from each of the original four color groups—on a Pye-Unicam 8800 U.V.-visible spectrophotometer and a Nicolet 60SX FTIR spectrometer.

Chemical analyses were obtained—from 83 samples ground to 200 mesh and screened from the three final color groups KH1, KH2/3, and KH4—by proton-induced X-ray emission (PIXE) analysis. This non-destructive method, which is similar in principle to energy-dispersive X-ray fluorescence (EDXRF), employs an accelerator to drive a high-speed stream of protons toward the target sample. Each element in the sample responds by producing characteristic X-rays, which are detected and counted; within minutes of exposure, a computer produces quantitative data over the entire chemical spectrum.

DESCRIPTION OF THE MATERIAL

Chemically, peridot is a magnesium-iron orthosilicate with the general formula $(Mg,Fe)_2SiO_4$. It is a member of the olivine group and, compositionally, belongs to an isomorphous series in which it lies closer to the end member forsterite (Mg_2SiO_4, at the low end of the R.I./S.G. scale) than to the other end member, fayalite (Fe_2SiO_4, with high R.I. and S.G.; Gübelin, 1975). Olivine is orthorhombic, with imperfect (010) and (100) cleavage and a Mohs hardness of 6.5 to 7. Optically, it is biaxial, with moderate to high birefringence.

Most of the "bombs" recovered at Kilbourne Hole were 10–25 cm (4–10 in.) long and showed evidence of weathering and limonite surface coloring, presumably from the decomposition of iron compounds leached to the nodule surface. One nonweathered "bomb" (approximately 25 × 15 × 7 cm) shown freshly broken in figure 4, weighed 4.5 kg. It does not appear that there are typical shapes for "bombs" that contain cuttable peridot (figure 6); any of the pieces is just as likely to reveal a mixture of fractured peridot, augite, diopside, and possibly enstatite and bronzite.

Figure 7. This collection of approximately 941 ct of typical facet-grade Kilbourne Hole peridot represents about five days of collecting and illustrates—with the exception of yellowish brown to dark brown—the range of colors found.

The collection illustrated in figure 7 represents the range of peridot colors, except pale yellowish brown and the darker browns, found at Kilbourne Hole in the course of five days of collecting. The surfaces of facetable pieces larger than 1 ct exhibit numerous conchoidal fractures and a "sandblasted" appearance typical of material found near the top of the eastern basalt rim and desert-sand slopes.

Although one notable specimen contained two large—128 ct and 26 ct—gem-quality pieces of rough (figure 8), most of the gem-quality material recovered by the author was small and produced jewelry-quality stones under 0.5 ct.

Only about 10% yielded gems over 0.5 ct and up to 10 ct. The cut stones tend to be very bright, with particularly fine clarity (figures 9 and 10). The author estimates that only 15%–20% of the material found is suitable for faceting because of the numerous fractures inherent in the rough.

None of the Kilbourne Hole material recovered to date exhibits asterism or chatoyancy, although both have been reported in the literature for peridot from other localities.

Figure 8. The best "bomb" found to date yielded two pieces of facetable rough weighing 128 and 26 ct.

Figure 9. These three clusters (0.12 to 2.00 ct) are representative of the three main color groups—KH1 (center), KH2/3 (top), and KH4 (bottom)—in which the Kilbourne Hole peridot occurs. Note the fine clarity. Photo by Shane McClure.

GEMOLOGICAL PROPERTIES

Color descriptions of representative specimens from the three color groups include: for KH1, light greenish yellow to yellowish green; for KH2/3, medium

Figure 10. This 1.43-ct Kilbourne Hole peridot is of optimum color and virtually flawless. Courtesy of Edward J. Gübelin; photo by Robert Weldon.

dark, slightly brownish, yellowish green; and for KH4, medium to dark yellowish brown.

Refractive indices vary in direct proportion to color variations from yellow through green to brown (see table 1). The observed ranges were: n_α = 1.654–1.673, n_β = 1.673–1.691, and n_γ = 1.691–1.709, with a birefringence of 0.034–0.038. Pleochroism is distinct, with color combinations for the three color categories of: (KH1) light yellow and light yellowish green, (KH2/3) medium yellow to orangy yellow and medium yellowish green, and (KH4) medium to dark brownish yellow and medium to dark yellowish brown. Specific gravities of 3.415 to 3.499 were obtained. All specimens remained inert to both long- and short-wave ultraviolet radiation.

SPECTROSCOPY

Absorption bands were observed in all specimens at 452, 473, and 640 nm, the last being relatively weak. A moderately strong band centered at about 492 nm was also observed with the prism spectroscope, but the diffraction-grating unit resolved it into two bands at about 497 and 489 nm. Spectrophotometry of eight samples (two from each original color group) revealed these and additional weak bands as follows: 402, 410, 453, 472, 487, 495, 530, and 634 nm (figure 11). As one might expect, all features were less apparent in the paler stones. These spectral features have all been observed previously in peridot from other localities, particularly those from Arizona (Farrell and Newnham, 1965; Burns, 1974; Koivula, 1981).

CHEMICAL COMPOSITION AND ORIGIN OF COLOR

The data obtained by PIXE chemical analyses of three samples of Kilbourne Hole peridot revealed compositions typical for peridot from around the world (table 1). Closer examination of the data, however, reveals information about the causes of color in the Kilbourne material. Mg:Fe ratios for the KH1 (greenish yellow to yellowish green) samples were on the order of 4.65:1, as compared to around 3.64:1 for the KH2/3 (yellowish green with olive green) and 2.52:1 for the KH4 (medium to dark brown with little or no green) samples. Table 1 also shows that, as Mg content decreases, both Cr and Ni also decrease, while Fe content and depth of color increase. Thus, it appears that neither Cr nor Ni contributes to an increase in green coloration.

TABLE 1. Gemological properties and chemical composition of three representative samples of Kilbourne Hole peridot.

Properties and elements	KH1	KH2/3	KH4
Color[a]	lt. gY	med. yG	med. yB
R.I. n_α	1.659	1.663	1.669
n_β	1.674	1.679	1.684
n_γ	1.693	1.698	1.705
S.G.	3.415	3.426	3.499
Chemistry[b] (wt.%)			
Mg	28.223	26.674	25.898
Si	16.576	15.821	16.081
K	0.013	0.017	0.016
Ca	0.078	0.058	0.098
Cr	0.027	0.013	0.010
Mn	0.096	0.116	0.152
Fe	6.067	7.324	10.280
Ni	0.234	0.192	0.174
Zn	0.004	0.003	0.006
O	48.679	49.776	47.275
Total	99.997	99.994	99.990

[a]*Color descriptions are as follows: lt. = light, med. = medium, g = greenish, y = yellowish, Y = yellow, G = green, B = brown.*
[b]*Analyses performed on the PIXE system of a General Ionex Corp. Tandetron accelerator with an intense proton beam of up to 3 MeV; a Tracor lithium-drifted silicon X-ray detector ; and a multichannel analyzer system.*

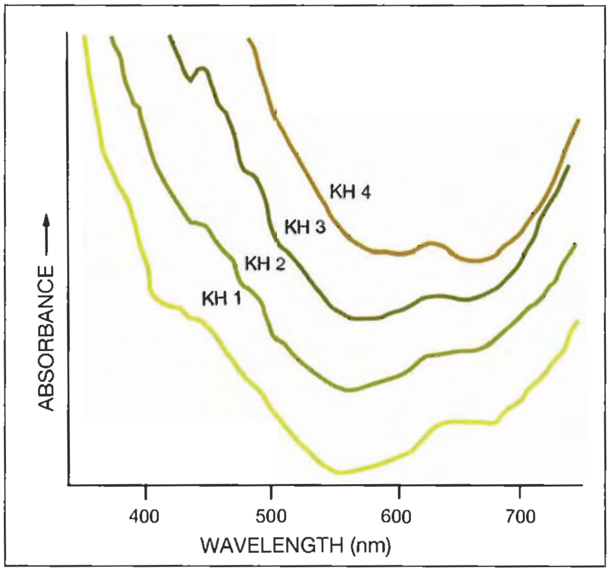


Figure 11. These U.V.–visible spectra were taken on representative samples of peridot from the major color groups found at Kilbourne Hole. The spectra were measured on parallel-window samples of similar thickness (approximately 1.5 mm) and recorded using a Pye-Unicam 8800 spectrophotometer.

Yellowish green peridot is a classic example of coloration by a transition metal ion, in this case Fe^{2+} (Farrell and Newnham, 1965). Traces of chromium have been reported as contributing to the green color (Arem, 1987), but no support for this was found here.

Spectrophotometry revealed essentially three components that, together, leave a transmission window centered around 550 nm, which corresponds to yellowish green (again, see figure 11). The first of these is an absorption tail that absorbs much of the red and orange. This feature has been observed in peridots from other localities and is related to near-infrared absorptions that are attributed to Fe^{2+} (Burns, 1974).

The second component is the series of bands in the visible range, most of which have also been attributed to Fe^{2+} (Farrell and Newnham, 1965). The suggestion that some are related to Mn^{2+} (Gunawardene, 1985) was not substantiated.

The third spectral component is a general increase in absorption from about 550 nm toward the ultraviolet, which contributes brown. Studies on synthetic forsterite (Weeks et al., 1974) and on other gem silicates and oxides (Fritsch and Rossman, 1987) indicate that this feature may arise from charge-transfer phenomena between oxygen and transition metal ions such as Fe^{3+} or Ti^{4+}. However, the iron-rich olivine end member fayalite is often amber colored in thin section regardless of Ti content (Deer et al., 1982), which suggests that Fe alone may be responsible.

MICROSCOPIC FEATURES

Several thousand carats of rough material collected by the author at Kilbourne Hole over a number of years were examined with the microscope. From these, a study collection of 2,213 samples was assembled that represents the complete range of inclusions observed. Although limited in variety by geologic mode of formation, the inclusions in Kilbourne Hole material, like those in peridots from other localities (Gübelin, 1974; Gübelin and Koivula, 1986), are gemologically diagnostic for peridot, if not for the locality. However, the "black" inclusions in Kilbourne peridots are notably smaller and fewer in number than those found in material from Arizona.

Four mineral inclusions were identified in Kilbourne Hole peridots: hercynite, forsterite, diopside, and biotite. Hercynite has not previously been described in peridots from other localities. Both primary and secondary fluid inclusions were also observed, as were the "lily pad" inclusions characteristic of peridot.

Hercynite. The most common type of mineral inclusion in Kilbourne Hole peridot, which seemed to be present in virtually all of the stones examined, is hercynite, a member of the spinel group. The inclusions are primarily opaque black octahedra and distorted octahedra, some flattened to an almost tabular habit. Tension fractures usually surround these inclusions, as a result of the expansion of the hercynite against the host peridot during formation (figure 12).

In appearance, the hercynite inclusions in Kilbourne Hole peridot resemble both chromite (Koivula, 1981; Koivula and Fryer, 1986) and chromian spinel (Dunn, 1974) as found in peridot from Arizona. Nevertheless, X-ray diffraction analysis of two separate crystals removed from a random selection of Kilbourne peridot fragments revealed their identity as hercynite ($Fe^{+2}Al_2O_4$). Thorough search of the gemological and mineralogic literature failed to disclose any mention of hercynite in peridot. All previous references to "black single-crystal" inclusions in peridot refer to them as "black euhedral chromite octahedra" or "dark reddish brown octahedra of chromian spinel and black chromite crystallites" or "a metallic protogenetic chromite crystal" (see, e.g.,

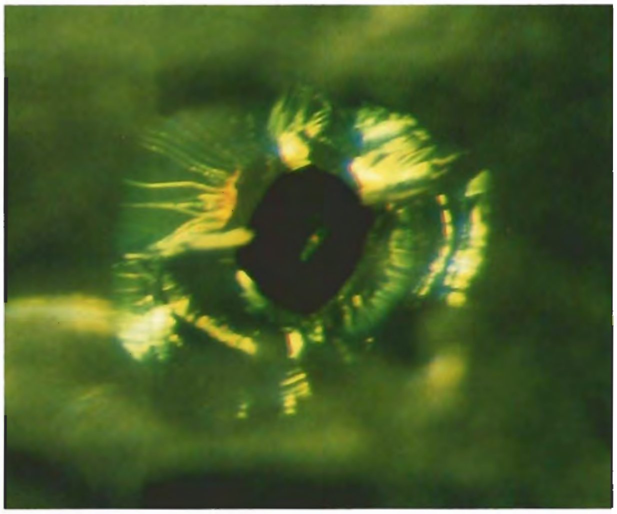


Figure 12. The most common mineral inclusion found in Kilbourne Hole peridot is hercynite, which is typically surrounded by a tension fracture, as shown here. Hercynite has not previously been observed in peridots from other localities. Photomicrograph by Edward J. Gübelin; magnified 40 ×.

Gübelin and Koivula, 1986). It is still possible, however, that some of the opaque black mineral inclusions in Kilbourne peridot are chromian spinel or chromite.

Forsterite. Peridot and forsterite are essentially the same mineral, so inclusions of the latter show virtually no relief from the surrounding peridot and are usually very difficult to detect. In Kilbourne Hole peridots, however, some forsterite inclusions exhibit enough interface to make them visible in standard darkfield illumination (figure 13). Some also have a different optic orientation, so they stand out with polarized light (figure 14). One small, essentially colorless rounded grain was partially freed from its peridot host for X-ray diffraction analysis; it was confirmed to be forsterite.

Diopside. Bright "emerald" green diopside crystals were also identified by X-ray diffraction analysis. These inclusions appear as transparent to translucent rounded protogenetic blebs of low relief with a "chrome" green color (figure 15) that is darker than that of the surrounding peridot. When the diopside crystals are very small, however, their color tends to blend into that of the peridot host. Diopside has also been reported in peridot from Arizona (Koivula et al., 1980; Koivula, 1981) and China (Koivula and Fryer, 1986).

Biotite. Biotite is perhaps the rarest mineral inclusion found in Kilbourne Hole peridot; only a single example was observed during this study, and identification was made visually. The inclusion consisted of translucent brown euhedral flakes of pseudohexagonal biotite mica (figure 16). Similar inclusions

Figure 13. A slight interface makes this forsterite crystal visible within the host Kilbourne Hole peridot. Photomicrograph by John I. Koivula; magnified 45 ×.

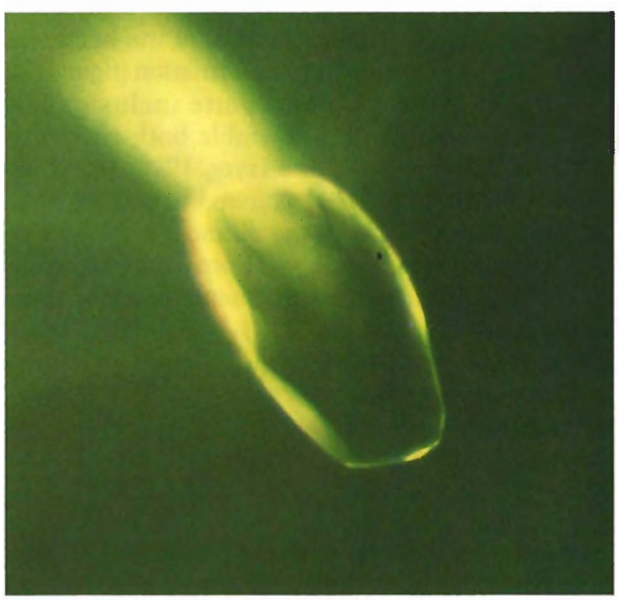
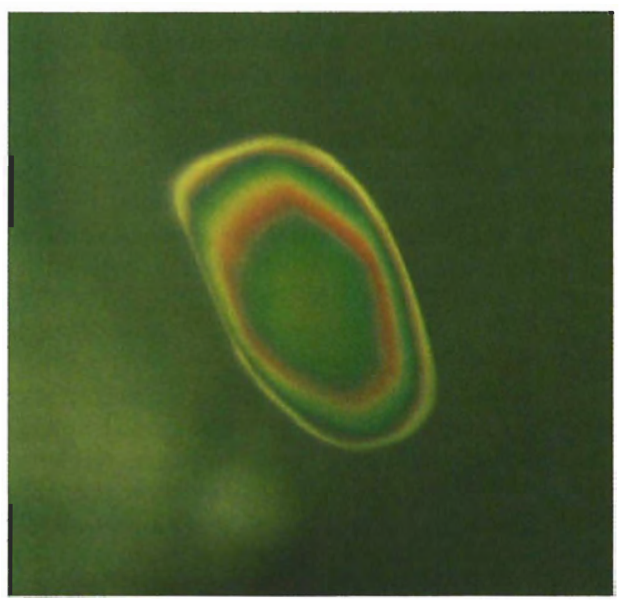


Figure 14. The same forsterite crystal shown in figure 13 also stands out in polarized light because of the difference in optic orientation from the host peridot. Photomicrograph by John I. Koivula; magnified 45 ×.



have been observed and identified as biotite in peridot from other localities, including Myanmar (Gübelin, 1974; Gübelin and Koivula, 1986), Arizona (Koivula, 1981), and China (Koivula and Fryer, 1986).

"Lily Pads." The "lily-pad" inclusion is common to peridots from virtually every locality. Kilbourne Hole peridots are no exception (figure 17), although the disks are smaller and significantly fewer in number than those observed in material from San Carlos, Arizona. These circular to ovoid disks, known as decrepitation halos, are cleavages that result from the rupturing of tiny fluid-filled (usually carbon dioxide and natural glass) negative crystals.

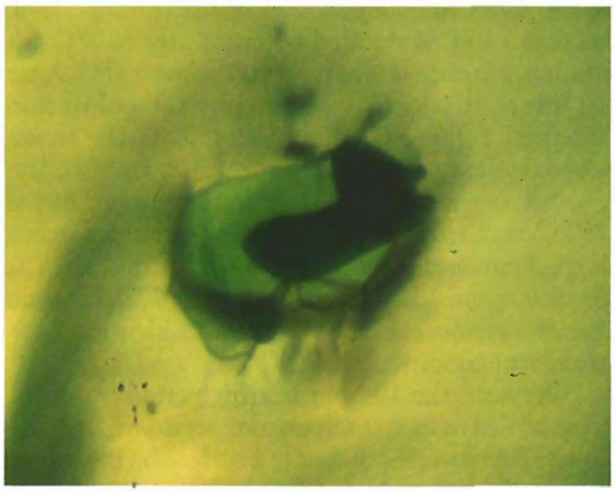
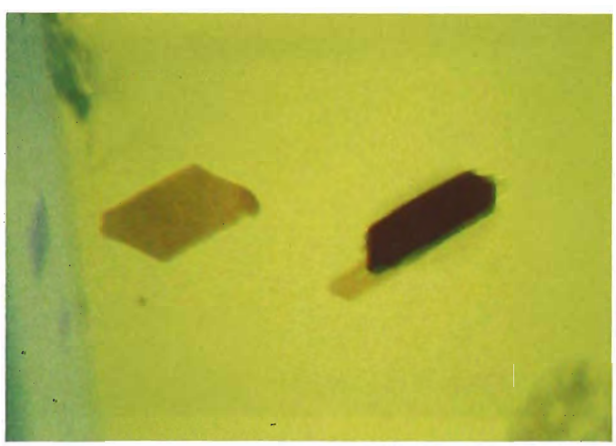


Figure 15. This "chrome" diopside inclusion, associated with black hercynite, exhibits the low relief and bright green color typical of this mineral. Photomicrograph by John I. Koivula; magnified 50 ×.

Figure 17. Decrepitation halos surrounding negative crystals, inclusion features descriptively known as "lily pads," are also found in Kilbourne peridots. Photomicrograph by Edward J. Gübelin; magnified 21 ×.

Figure 16. These pseudohexagonal, translucent brown biotite crystals were the only example of this mineral seen in the study collection of Kilbourne Hole peridot. Photomicrograph by Edward J. Gübelin; magnified 26 ×.



Glass Blebs. Natural glass occurs in Kilbourne Hole peridot as blebs of various shapes, most commonly semicircular to somewhat oval, but often extremely elongated (figure 18). In all cases, examination with polarized light revealed behavior consistent with an amorphous compound such as glass.

Identification was confirmed by heating experiments. All of these inclusions contained shrinkage-related spherical bubbles. None of the bubbles was observed to move or change size during the slight heating that occurs on prolonged exposure to a microscope lamp. This, and the presence of more than one bubble per inclusion, proves that the fluid that fills the negative crystals has the high viscosity associated

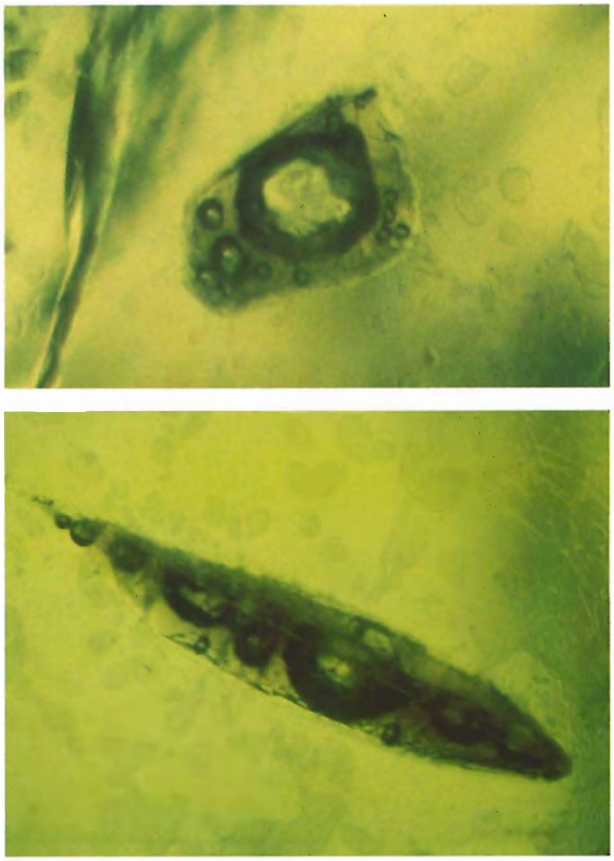


Figure 18. Natural glass inclusions, in a variety of shapes, were seen in several specimens of Kilbourne Hole peridot. All contained gas bubbles. Photomicrographs by John I. Koivula; magnified 50 ×.

with glass. Additional heating experiments performed by John Koivula of GIA revealed that these blebs soften at just below 1000°C, consistent with glass.

Smoke-like Veils. Previously noted in peridots from Arizona and China (Koivula, 1981; Gübelin and Koivula, 1986; Koivula and Fryer, 1986), smoke-like veiling is relatively common in Kilbourne Hole peridots (figure 19). It results from incomplete solid solution that occurs as the peridot is brought to the earth's surface and cools in the basalt, producing visible strain caused by dislocations (Kohlstedt et al., 1976). These veils always look like ghostly white streamers when viewed with darkfield illumination.

"Fingerprints." Partially healed secondary fractures in the form of fingerprint-like patterns (figure 20) were observed in a few of the Kilbourne Hole peridots. They resemble those found in peridot from Myanmar, Egypt, and China (Gübelin and Koivula, 1986; Koivula and Fryer, 1986).

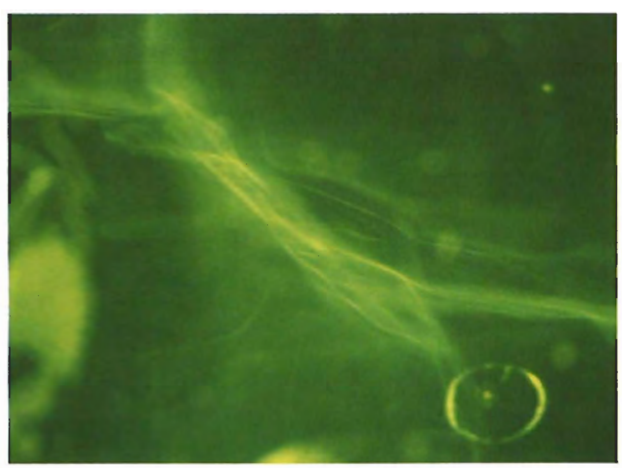
HEAT TREATMENT AND IRRADIATION

Co^{60} irradiation of both faceted and rough specimens of Kilbourne peridot, including the samples described previously under "Chemical Composition," produced no observable change in color.

Twenty samples each from KH1 through KH4 were heat treated in air at 50° increments, from 100° to 750°C, for 10-hour periods. The rate of temperature increase was controlled by computer to 2°C per minute. No change was observed below 650°C. After 10 hours at 650°C, a brown surface coloration appeared. Following the period at 700°C, the brown surface coloration was accompanied by an oxide layer with a metallic luster. A final 10-hour heating, at 750°C, resulted in a "peacock-blue" oxidation over a layer of brown color. Similar iridescence was noted by Stockton and Manson (1983) on the surface of an Arizona peridot subjected to virtually identical heat-treatment conditions.

Between the 10-hour heating periods, samples were cooled to room temperature, sectioned, and polished. This revealed that only a surface layer—which was easily removed—had been affected. Where fractures existed in the original specimen, the oxidation invaded the fractures and appeared as orangy brown "stains."

Figure 19. Another relatively common internal feature of Kilbourne Hole peridot is smoke-like veiling. Photomicrograph by John I. Koivula; magnified 35 ×.



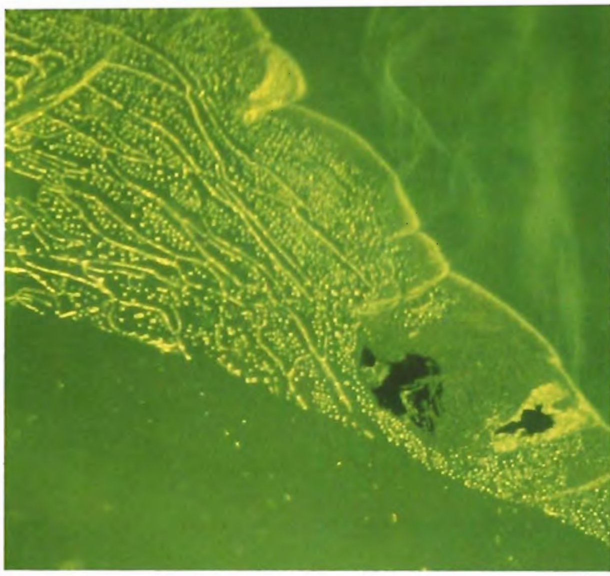


Figure 20. Also found in Kilbourne Hole peridots were partially healed secondary fractures that form "fingerprint" inclusions. Photomicrograph by John I. Koivula; magnified 40 ×.

CONCLUSION

Kilbourne Hole produces exceptionally bright and lively faceted peridots with clarity and color comparable to fine yellow-green peridot from other gem localities. The gemological properties and chemical composition are consistent with those recorded for peridot. However, the Kilbourne Hole stones contain one inclusion, hercynite, that has not been reported in peridot from other sources. Moreover, Kilbourne Hole peridot virtually lacks the large black inclusions found in commercially available Arizona material. The body color does not respond to heat or radiation treatment.

While the Kilbourne Hole material appears to be plentiful, most cut gems are smaller than 1 ct. Currently, the deposit is not being actively worked.

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