PERIDOT AS AN INTERPLANETARY GEMSTONE

By John Sinkankas, John I. Koivula, and Gerhard Becker

The stony-iron meteorites known as pallasites are famed for the areas of yellowish green olivines they contain. Since the earliest description by Peter Simon Pallas in the 18th century, reference has been made to the gem-like nature of these meteorite "inclusions." Not until the early 20th century, however, was there any record of a faceted pallasitic olivine, and only recently have a handful of stones been available for gemological examination. Study of nine peridots faceted from pallasites revealed properties within the range known for peridots plus a common inclusion feature never before observed in their terrestrial counterparts.

Peridot, the gem variety of olivine, is relatively soft and fragile when compared to diamond, corundum, spinel, and a number of other gemstones. It also is known to shatter on exposure to high temperatures, such as those encountered in jewelry manufacturing. Nevertheless, some peridots are able to survive the journey from outer space and a fiery passage through the Earth's atmosphere as a major component of the stony-iron meteorites known as pallasites.

ABOUT THE AUTHORS

Dr. Sinkankas is a retired naval captain residing in La Jolla, California; he has authored numerous books and articles on lapidary work, mineralogy, and gem and mineral collecting. Mr. Koivula is chief gemologist at the Gemological Institute of America, Santa Monica, California. Mr. Becker, a prominent gem designer and lapidary, is head of Friedrich August Becker, Idar-Oberstein, Germany.

Acknowledgments: The authors thank George Harlow, of the American Museum of Natural History, in New York, for arranging the loan of the Eagle Station, Kentucky, pallasitic peridot; Robert Haag, of Robert A. Haag—Meteorites, Tucson, Arizona, and Dale Dubin, of Ft. Meyers, Florida, for providing the study stones faceted from the Esquel, Argentina, pallasite; Andreas Becker, of Friedrich August Becker, Idar-Oberstein, for faceting the Esquel peridots; and Christopher P. Smith, now of the Gübelin Gemmological Laboratory, Lucerne, Switzerland, for recording the gemological properties of several of the study samples.

Gems & Gemology, *Vol. 28, No. 1, pp. 43-51.*

The ability of some peridot to withstand high temperatures is demonstrated by the occurrence of transparent, facetable masses and crystals in volcanic and metamorphic environments. Notable occurrences include the basalts of Peridot Mesa, Arizona (Sinkankas, 1959; Koivula, 1981) and the marbles of the Mogok region, Myanmar (Burma). The latter yields faceted gems in excess of 100 ct. A lower-temperature hydrothermal environment characterizes the beautiful, sharply terminated crystals that have been found since antiquity in veins on Zabargad (St. John's Island) in the Red Sea (Moon, 1923; Wilson, 1976; Gübelin, 1981; Bancroft, 1984). Other occurrences of olivine, including peridot, are recorded by Hintze (1897) and Doelter (1914). Summaries of properties are also given by Deer et al. (1966), Wilson (1976), Koivula (1981), and Stockton and Manson (1983).

Although much has been written about pallasites since they were first described in 1776, including comprehensive reports on the olivines contained therein, the historic literature carries only a few references to the gem potential of these olivines. Recently, however, one of the authors (GB) supervised the faceting of several olivines removed from a large pallasite that was found in Esquel, Argentina. Eight of these were studied for this report (seven are illustrated in figure 1). The authors also obtained from the American Museum of Natural History a peridot faceted several decades ago from the Eagle Station, Kentucky, pallasite (figure 2). This article

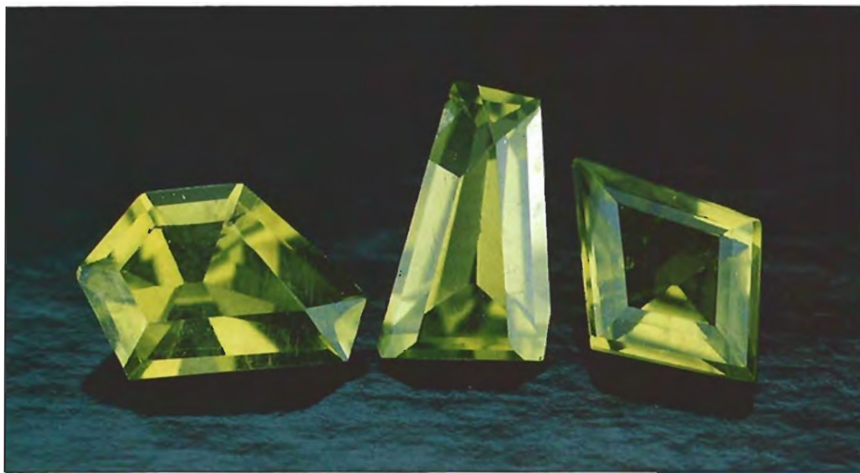


Figure 1. All of these peridots were faceted by Andreas Becker from olivines extracted from the Esquel, Argentina, pallasite. The stones on the right range from 0.25 to 1.39 ct and are courtesy of Robert A. Haag; the stones on the left range from 0.39 to 0.51 ct and are courtesy of Dale Dubin. Photos © Tino Hammid.

reviews historic references to these unusual olivines and presents the results of a gemological examination of nine faceted pallastic peridots.

OLIVINE IN METEORITES

Extraterrestrial olivine is abundant in relatively large grains only in pallasites. These stony-iron meteorites were named for the famous German naturalist, geologist, and traveler Peter Simon Pallas (1741–1811), who first described the type specimen—a 680-kg (McCall, 1973) mass found near the town of Krasnoyarsk, Siberia, in 1749 (Pallas, 1776). This specimen was originally called the "Pallas iron" but, as is now customary, has been renamed Krasnoyarsk after the locality. In Pallas's time, the true origin of meteorites was the subject of much wonder and speculation. Many scientists regarded them as peculiar products of the Earth's crust; only the more daring suggested an extraterrestrial origin. The strongest arguments for the latter were advanced by Ernst Florens Friedrich Chladni (1756–1827), a German scientist best known for his studies of sound and its propagation, in his monograph on the Pallas iron (Wasson, 1974, introduction to facsimile of Chladni, 1794).

In speaking of extraterrestrial, Earth-like bodies that could have provided meteorites, Wasson states elsewhere that "pallasites were probably formed by violent events that mixed mantle and core materials" (1985, p. 93), thus accounting for the spongy structure of the nickel-iron alloy that encloses the olivine nodules. The metallic portions of pallasites consist of kamacite and plessite, two nickel-iron alloys believed to have been the principal constituents of the core, while the olivine itself was derived from the mantle. Much of the olivine is sufficiently low in iron to be classed as peridot, which approaches forsterite (Mg_2SiO_4), the magnesium-silicate end member of the olivine group. As iron substitutes for the magnesium, the color changes toward brown to fully black in the opposite, iron-silicate end member, fayalite (Fe_2SiO_4). For descriptions and remarks on pallasites in general, see Dodd (1986), Farrington (1915b), Hintze (1897), Krinov (1960), McCann (1973), and Wasson (1985). Farrington, among others, called the transparent olivine in pallasites "chrysolite," a term once commonly used to designate peridots that were more yellowish green (Bristow, 1861). The term is now in disfavor; for an excellent discussion of peridot nomenclature, see Gübelin (1981).

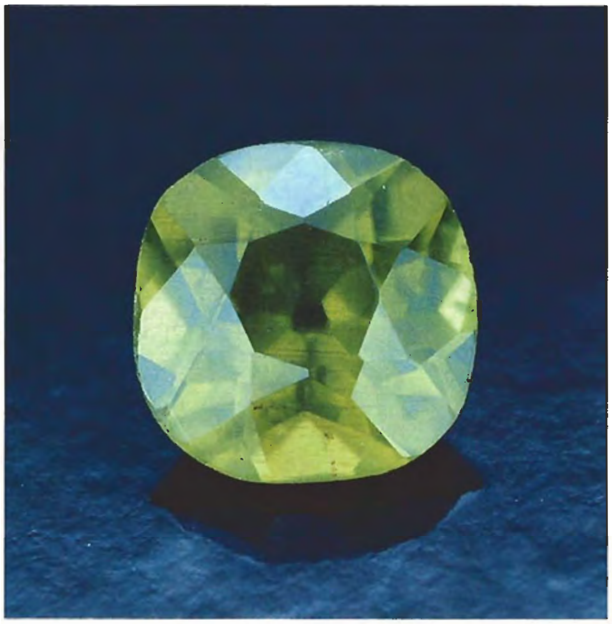


Figure 2. This 0.52-ct peridot was faceted from olivine found in the Eagle Station, Kentucky, pallasite. It is currently part of the collection at the American Museum of Natural History, New York (catalogue no. 42748). Photo © Tino Hammid.

PALLASITIC OLIVINE AS A POTENTIAL GEM MATERIAL

Pallas himself hinted at the gem-like appearance of the Krasnoyarsk pallasite olivines, which he described as "rounded and elongated drops of a very brittle but hard, amber-yellow, transparent glass" (Farrington, 1915b, p. 182). Farrington also noted that "Count Bournon in 1802 showed that this was similar to terrestrial chrysolite and Howard in the same year [see Brown, 1953, p. 1802] gave an analysis [that] indicated the mineral to be chrysolite."

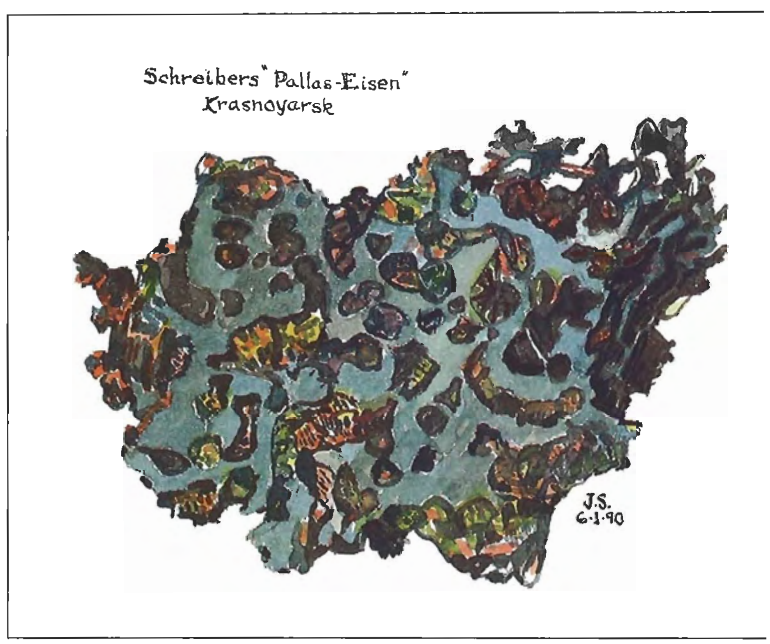
The earliest published illustrations of meteorites, one of which includes a specimen of the Pallas iron, are engravings in Schreiber (1820). From the reproduction of the Krasnoyarsk pallasite shown in figure 3, it is evident that the olivine nodules are prominent and largely transparent. However, so far as is known, no gem has been cut from this olivine.

Noted American gemologist George Frederick Kunz (1856–1932) also suggested the suitability of meteoritic olivine for gems. He first remarked on the transparent olivine in the Glorieta Mountain, New Mexico, pallasite in 1886. Later (1890, p. 101), he reported that he had obtained from this meteorite "some peridots of 1 carat weight that were transparent and yellowish-green in color." Unfortunately, he did not state whether any were cut into gems.

FACETED PALLASITIC PERIDOTS IN HISTORY

It is likely, however, that George F. Kunz had a hand in the extraction and perhaps even faceting of another pallasitic peridot, the stone shown here as figure 2. The catalogue, *A Collection of Gems, American and Foreign, Cut and in Their Natural State . . .*, published by Tiffany and Co. for the 1900 Paris Exposition, reports the presence of an olivine from the Eagle Station, Kentucky, meteorite. This Tiffany catalogue was no doubt prepared by Kunz, who had first described the Eagle Station meteorite in 1887. According to George Harlow of the American Museum (pers. comm., 1992), the original accession card, in the handwriting of then-curator Louis Pope Gratacap, refers to a "cut stone and chips" as being the same listed in the Tiffany catalogue as no. 347. Unfortunately, the Tiffany catalogue does not state whether this stone was faceted, and there is no date on the Gratacap accession card, although we know the peridot must have been cut before Gratacap's death in 1918. In light of Kunz's propensity for faceting any

Figure 3. The transparent character of the olivines in the Krasnoyarsk pallasite are evident in this watercolor reproduction, by John Sinkankas, of the color engraving of a fragment of the original pallasite shown in Plate VIII of Schreibers (1820).



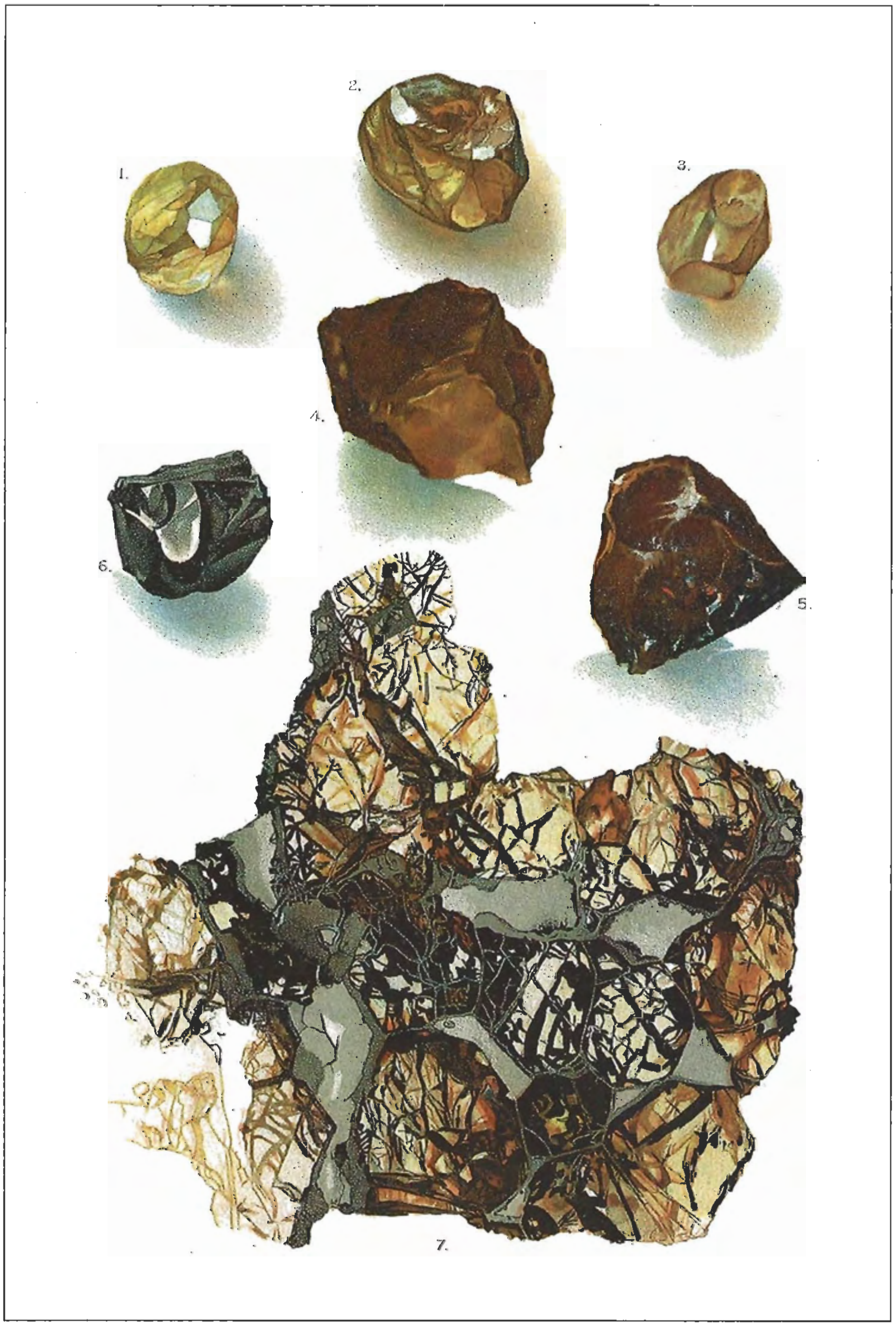


Figure 4. Plate XXVII from Mingaye (1916) shows a slice of the Molong, New South Wales, pallasite together with various pieces removed from the meteorite and, in the upper left-hand corner, the faceted gem cut from one of the Molong olivines.

American material that could be cut, it may have been faceted when it was displayed at the Paris Exposition. This stone may actually be the first faceted pallasitic peridot of record.

The earliest confirmation of a faceted extraterrestrial peridot is given in the description by Mingaye (1916) of the pallasite found in 1912 near Molong, New South Wales, Australia. Mingaye described the circumstances of the discovery, the precise location, the weights of the two masses comprising this meteorite (approximately 204 lbs. [93 kg] and 28 lbs. [13 kg]), and the chemical compositions of the metallic portion and the olivine. Light yellow olivine chosen for analysis gave principal components of SiO_2 (40.40 wt.%), FeO (9.59 wt.%), and MgO (47.70 wt.%), which falls mid-range for typical forsterite compositions (Arem, 1987). Mingaye also found a specific gravity of 3.357 and noted that "the olivine ranges from dark-black, shades of red, to pale lemon yellow in colour, the crystals being largely fractured in the cooling of the meteorite in falling through space to reach earth. These were found cemented in the solid nickeliferous iron particles . . . and *one small piece free from flaws has been cut by the Department Lapidary as a gem stone.*"

The gem is shown in the upper left-hand corner of Mingaye's Plate XXVII, here reproduced as figure 4. The same plate also shows a slice of the Molong pallasite, which indicates the volume occupied by olivine as compared to the metallic constituents. The text identifies Mr. W. H. Gilding of the New South Wales Department of Mines as the lapidary but, unfortunately, provides no further information. According to Dr. G. S. Gibbons of the Geological Survey of New South Wales (pers. comm., 1990), neither the slice nor the objects associated with it can now be found, due to relocation of the department's collections.

Tcherwinski (1916) provided additional data from his study of a 109.4-gram fragment of the Molong pallasite. He noted that the iron is "much decomposed," but the "olivine seems here and there quite fresh . . . light yellow colour, inclining to green." Tcherwinski also commented that he "could not, under the microscope, discover the primary inclusions" in the olivine.

A much more recent attempt to obtain a gem from meteoritic peridot is recounted by Nininger (1972), who collected most of the pieces of the Brenham, Kansas, pallasite, which fell in the late 19th century, and extracted various fragments for study and dispersal. He noted (pp. 83–84) that "in one instance my cut revealed a perfectly beautiful crystal, transparent but of greenish golden hue, which I determined to remove and have mounted in a ring for my wife . . . I thought. How romantic, to present a ring with a gem cut *out of this world*!" The peridot was taken to a jeweler, who was cautioned that it must be treated carefully. Finally, after a long delay, the jeweler admitted that he had broken the gem while mounting it. Nininger closed his anecdote with the remark that "I have never found another perfect crystal."

FACETING PALLASITIC PERIDOT

In 1990, one of the authors (GB) noted relatively large transparent to translucent areas in slices taken from the Esquel, Argentina, pallasite, which had recently been acquired by meteorite dealer Robert Haag. The author identified several olivines that promised to yield small faceted gems and took them back to Idar-Oberstein, Germany, where they were subsequently faceted by Andreas Becker (figure 5).

The olivine "raisins" extracted from the pallasite slices were sawed with extremely thin diamond-charged saw blades, then preformed on diamond-charged laps, and finally faceted using the traditional, fully handheld "jamb-peg." The flexibility of the jamb-peg enabled Becker to obtain maximum recovery from the rough. Polishing was performed on an alloy lap of 60% lead and 40% tin, charged with "diamantine" powder (aluminum oxide). Further details of this cutting process have been reported by Frazier and Frazier (1992).

Compared to the San Carlos basalt peridots, the Esquel olivines appeared to be more brittle, perhaps because of the greater stresses imposed on them during growth and, later, celestial flight and impact. Also because of these stresses, most of the olivines in the Esquel pallasite are heavily fractured. Even with a relatively transparent piece, the yield is only 15% to 20%. To date, Mr. Becker has faceted fewer than 30 peridots extracted from the Esquel pallasite. Although additional gem material is undoubtedly present in this meteorite, we do not know how much and speculate that the sizes will continue to be small.

Figure 5. Andreas Becker faceted the pallasitic peridots on the right from transparent pieces of olivine (like those at center) removed from slices of the Esquel, Argentina, pallasite similar to that shown on the left.

GEMOLOGICAL PROPERTIES OF PALLASITIC PERIDOTS

Over the last year, one of the authors (JK) and a colleague, Chris Smith, studied the gemological properties of a total of nine faceted meteoritic peridots (again, see figures 1 and 2), eight from the Esquel fall mentioned above and one from the Eagle Station pallasite loaned by the American Museum of Natural History (new catalogue no. 42748). The properties obtained are reported in table 1 and discussed below.

Visual Appearance. The samples range in size from a 0.25-ct round mixed cut (3.97–4.06 × 2.18 mm) to a 1.39-ct triangular step cut (7.14 × 7.00 × 4.82 mm). They range in color from greenish yellow to yellowish green in light to medium-dark tones. Diaphaneity varies from transparent to translucent, depending on the abundance of inclusions. Compared to peridots of terrestrial origin, we found the colors to be less vivid and to be somewhat muddy in several specimens.

Refractive Index. All of the gems were well polished, permitting good optical contact with the refractometer hemicylinder. We obtained refractive indices and birefringence for each of the nine gems using a near monochromatic, sodium-equivalent light source and a Duplex II refractometer. The values obtained (see table 1) were consistent with those known for terrestrial peridots from various localities, although the R.I. of the Eagle Station stone was unusually high. According to Dr. Brian Mason (pers. comm., 1992), who has studied olivines from both pallasites, the higher R.I. for this stone is to be expected in light of the significantly higher Fe content of the olivines from the Eagle Station material as compared to those from Esquel and most other pallasites.

With the refractometer, the optic character was found to be biaxial (confirmed with a polariscope), with the optic sign varying between –, +, and +/–.

Specific Gravity. All of the stones sank relatively slowly in methylene iodide (S.G. = 3.32), with only very slight differences in the sink rate. From this, the specific gravity of the nine gems was estimated to be 3.4.

Next, the samples were weighed hydrostatically on an appropriately modified Mettler CM1200 carat-weight electronic balance. Values averaged from three separate determinations done on each stone at room temperature ranged from 3.37 ± 0.05 on the 0.34-ct Esquel stone to 3.47 ± 0.05 for the Eagle Station stone (again, see table 1). These values, too, are within the accepted range for peridot.

Ultraviolet Fluorescence. Under darkroom conditions, all nine gems were exposed to both long-wave and short-wave ultraviolet radiation. As expected for peridot, the stones proved to be inert and without phosphorescence.

Spectroscopy. To observe the visible-light absorption characteristics of the nine pallasitic peridots, we used three different tabletop-model spectroscopes—a Beck prism spectroscope, a GIA GEM Instruments Discan diffraction grating spectroscope, and a new prototype prism spectroscope also from GIA GEM Instruments—on all nine stones. Absorption bands were noted at approximately 456 nm, 474 nm, and 495 nm. The larger and/or darker the stone was, the stronger the absorption features were. The spectra observed in these pallasitic peridots are virtually identical to those shown by their terrestrial counterparts (Liddicoat, 1989).

TABLE 1. Gemological properties of nine pallasitic peridots[a].

Locality	Weight (ct)	Refractive index α	β	γ	Optic character Biaxial	Specific gravity
Argentina	0.25	1.655	1.675	1.690	–	3.42 ± 0.05
Argentina	0.34	1.652	1.670	1.688	+/–	3.37 ± 0.05
Argentina	0.39	1.656	1.670	1.691	+	3.44 ± 0.05
Argentina	0.40	1.656	1.670	1.691	+	3.42 ± 0.05
Argentina	0.51	1.656	1.670	1.691	+	3.43 ± 0.05
Kentucky	0.52	1.669	1.688	1.705	–	3.47 ± 0.05
Argentina	0.53	1.655	1.673	1.691	+/–	3.38 ± 0.05
Argentina	1.25	1.656	1.670	1.691	+	3.42 ± 0.03
Argentina	1.39	1.650	1.671	1.690	+	3.38 ± 0.02

[a]*See text for details of testing methods used.*

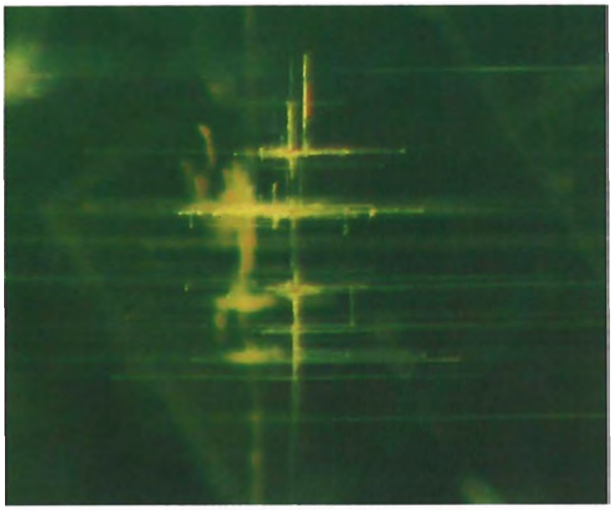


Figure 6. All nine of the pallasitic peridots studied contained acicular inclusions of an unknown material oriented in a plane at what appears to be 90° to one another. These are possibly formed by stress- and heat-caused alteration of—and/or exsolution from—the host olivine. Such inclusions have not been reported in peridots from any terrestrial locality. Photomicrograph by John I. Koivula; magnified 25 ×.

Figure 7. Sometimes the acicular inclusions are so dense that the host is rendered translucent. It is possible that such pallasitic peridots would form four-rayed stars if properly oriented and cut into cabochons. Photomicrograph by John I. Koivula; magnified 25 ×.

Pleochroism. With a calcite dichroscope and a white light source, weak to very weak pleochroism was noted, in various shades of green and yellow with slight brown overtones.

Chelsea Filter Reaction. When examined through the Chelsea color filter with a fiber-optic light source, all of the samples appeared to have essentially the same color as the filter itself (yellowish green). The strength of the observed color varied with the depth of color of the stone being examined.

Internal Characteristics. In several of the stones, inclusions were visible with little or no magnification. When examined using a gemological microscope, all of the stones revealed two sets of light yellow-brown acicular inclusions that appeared to be oriented at 90° to each other (figure 6). These inclusions possibly formed as a result of stress- and heat-induced alteration of and/or exsolution from the host olivine. A study of the available literature on inclusions shows that this type of acicular inclusion has never been reported in terrestrial peridots. It is therefore suggested that these inclusions can be considered as highly diagnostic for pallasitic peridots.

In the two largest stones, the acicular inclusions were so abundant that the stones appeared translucent (figure 7). If such stones were properly oriented and cut *en cabochon*, they might yield gems that display asterism.

Fractures or cleavages that reached the surface of these stones almost always contained red-brown iron oxide staining similar to that shown in the Molong pallasite (again, see figure 4). In the 1.25-ct oval sample, reddish brown iron-stained patches oriented in cleavage planes were observed (figure 8). These might be the result of the oxidation of tiny nickel-iron particles derived from the parent meteorite. These patches also showed colorful reflective iridescence when viewed in incident white light (figure 9). Since all of the patches reflected light at the same angle of illumination, all were oriented in the same plane.

While several stones contained what appeared to be tiny black particles, these were generally too small to resolve clearly. The 1.39-ct triangular step cut, however, contained an obviously rounded particle with a dark metallic luster that measured 0.6 mm in diameter (figure 10). Because of the dark color, metallic luster, immediate presence of iron oxide–colored staining, and known association with nickel-iron meteorites, this and similar dark particles in pallasitic peridots may be elemental nickel-iron. To prove this, however, some material would have to be sacrificed for chemical analysis.

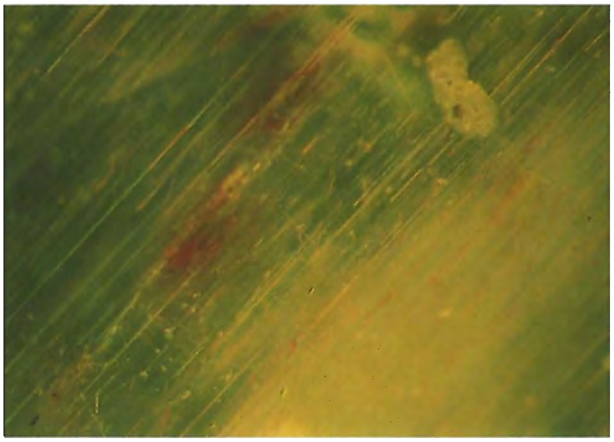


Figure 8. The 1.25-ct stone contained reddish brown, iron-stained patches oriented in cleavage planes. These may be the result of the oxidation of tiny nickle-iron particles derived from the parent meteorite. Photomicrograph by John I. Koivula; magnified 30 ×.

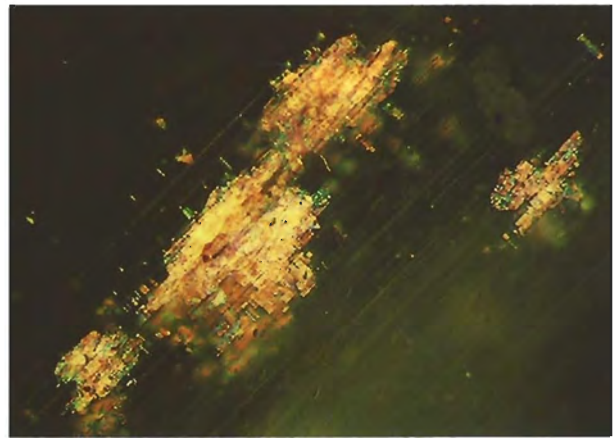


Figure 9. The reddish brown, iron-stained patches shown in figure 8 were reflectively iridescent when viewed in incident light, and all proved to be oriented in the same plane. Photomicrograph by John I. Koivula; magnified 30 ×.

CONCLUSION

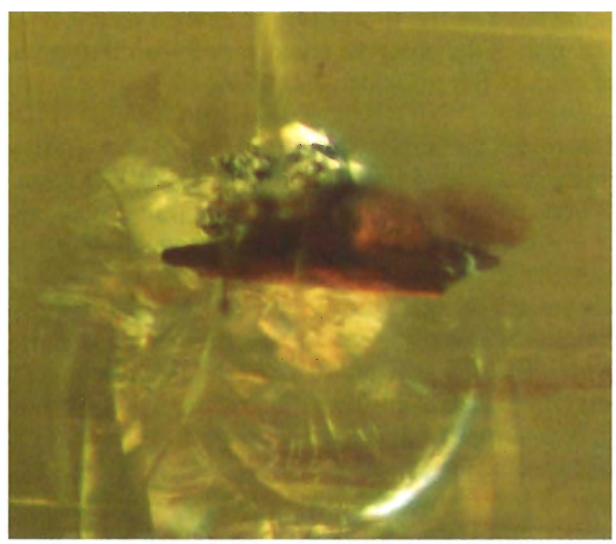
The olivine-rich meteorites known as pallasites sometimes contain areas of olivine that are large and transparent enough to yield small faceted gems of the peridot variety. To date, however, few such stones have been cut and they must, therefore, be counted as among the rarest of all gems.

The earliest faceted specimen may well be the Eagle Station, Kentucky, stone in the collection of the American Museum of Natural History in New York. We know that an olivine displayed by Tiffany & Co. in 1900 was described as "cut" in an American Museum accession card that must have been written before 1918. A more certain date is ascribed to the gem cut from the Molong, New South Wales material; this fall was discovered in 1912 and, by the time Mingaye furnished his description and color plate in 1916, the gem had already been cut. Another attempt at gem use of pallasitic peridot—this time from the Brenham, Kansas, pallasite—was made by H. H. Nininger some time in the late 1920s. The fortunate appearance of the olivine-rich Esquel meteorite and the extraction and cutting of faceted stones therefrom by Andreas Becker greatly enlarges our resources of this extreme rarity among gems.

The pallasitic peridots examined for this study proved to be remarkably similar to terrestrial peridots. The most notable difference is the presence of acicular inclusions in the Esquel and Eagle Station material that have never been recorded in terrestrial peridots. While substantial differences in properties were noted between the material from the two meteorites, these appear to be related to the special character of the Eagle Station olivines (B. Mason, pers. comm., 1992).

Numerous museum collections around the world contain specimens of pallasites with olivines suitable for faceting into gems, although most finished stones would weigh less than one carat. Experience with the cutting of the Esquel stones suggests that no special problems should be anticipated in preforming, faceting, and polishing pallasitic peridots, aside from their tendency toward brittleness.

Figure 10. The 1.39-ct peridot contained a 0.6-mm-diameter rounded particle with a dark metallic luster. Such particles may be composed of elemental nickel-iron. Photomicrograph by John I. Koivula.



REFERENCES

Arem J.E. (1987) *Color Encyclopedia of Gemstones*, 2nd ed. Van Nostrand Reinhold, New York.

Bancroft P. (1984) *Gem and Crystal Treasures.* Privately published, Fallbrook, CA.

Bristow H.W. (1861) *A Glossary of Mineralogy.* Longman, London.

Brown H., Kullerud G., Nichiporuk W. (1953) *A Bibliography on Meteorites.* Chicago University Press, Chicago, IL.

Chladni E.F.F. (1794) *Ueber den Ursprung der von Pallas gefundenen und anderer ihr ähnlicher Eisenmassen.* Riga, [4], facsimile reprint by Organizing Committee, 37th Meeting, Meteoritical Society, Los Angeles, 1974, with introduction by J.T. Wasson.

Deer W.A., Howie R.A., Zussman T. (1966) *An Introduction to the Rock-forming Minerals.* John Wiley, New York.

Dodd R.T. (1986) *Thunderstones and Shooting Stars: The Meaning of Meteorites.* Harvard University Press, Cambridge, MA.

Doelter C. (1914) *Handbuch der Mineralchemie*, Vol. 2. Theodor Steinkopff, Dresden and Leipzig.

Farrington O.C. (1915a) Catalog of the meteorites of North America, to January 1, 1909. *Memoirs of the National Academy of Sciences*, Vol. 13, Washington, DC.

Farrington O.C. (1915b) *Meteorites: Their Structure, Composition, and Terrestrial Relations.* Privately published, Chicago, IL.

Farrington O.C. (1916) Catalogue of the collection of meteorites. *Field Museum of Natural History Publication 188, Geology Series*, Vol. 3, No. 10, pp. 231–312.

Frazier S., Frazier A. (1992) Heavenly peridot. *Lapidary Journal*, Vol. 46, No. 2, pp. 36–40.

Gübelin E. (1981) Zabargad: The ancient peridot island in the Red Sea. *Gems & Gemology*, Vol. 17, No. 1, pp. 2–8.

Hintze C. (1897) *Handbuch der Mineralogie*, Vol. 2. Veit & Comp., Leipzig.

Koivula J.I. (1981) San Carlos peridot. *Gems & Gemology*, Vol. 17, No. 4, pp. 205–214.

Krinov E.L. (1960) *Principles of Meteoritics.* Pergamon Press, New York.

Kunz G.F. (1886) Further notes on the meteoric iron from Glorieta Mountain, New Mexico. *American Journal of Science*, 3rd series, Vol. 32, pp. 311–313.

Kunz G.F. (1890) *Gems and Precious Stones of North America.* Scientific Publishing Co., New York.

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

McCall G.J.H. (1973) *Meteorites and Their Origins.* John Wiley, New York, p. 21.

Mingaye J.C.H. (1916) Notes on the Molong meteorite. *Records, Geological Survey, New South Wales*, Vol. 9, Part 3, pp. 161–165.

Moon F.W. (1923) *Preliminary Geological Report on Saint John's Island (Red Sea).* Geological Survey Egypt, Cairo.

Nininger H.H. (1972) *Find a Falling Star.* P.S. Eriksson, New York.

Pallas P.S. (1776) *Reisen durch verschiedene Provinzen des rüssischen Reichs, 1771–1773.* St. Petersburg, Russia.

von Schreibers C. (1820) *Beyträge zur Geschichte und Kenntniss meteorischer Stein- und Metall-Massen, und der Erscheinungen, welche deren Niederfallen zu begleiten pflegen.* J.G. Heubner, Vienna, Austria.

Sinkankas J. (1959) *Gemstones of North America.* Van Nostrand, New York.

Stockton C.M., Manson D.V. (1983) Peridot from Tanzania. *Gems & Gemology*, Vol. 19, No. 2, pp. 103–107.

Tcherwinski P. (1920) The pallasite of Molong, New South Wales (Australia). Transl. by Dr. C. Anderson, Australian Museum, *Records of the Geological Survey of New South Wales*, Vol. 9, Part 4 (for 1919), pp. 192–196.

Wasson J.T. (1985) *Meteorites: Their Record of Early Solar-System History.* Freeman, New York.

Wilson W.E. (1976) Saint John's Island, Egypt. *Mineralogical Record*, Vol. 7, No. 6, pp. 310–314.