CHARACTERIZATION OF PERIDOT FROM SARDINIA, ITALY

Ilaria Adamo, Rosangela Bocchio, Alessandro Pavese, and Loredana Prosperi

Gem-quality peridot is occasionally found as mantle xenoliths within basalts near Pozzomaggiore, in northwestern Sardinia, Italy. The gemological properties and spectroscopic features of this material are consistent with the measured chemical composition of $Fo_{91}Fa_{9}$, typical of peridot from other localities worldwide. Although not yet mined commercially, this stone represents a promising gem material.

Peridot has been reported from many sources worldwide, but the localities with historical or contemporary commercial importance are Zabargad (Egypt), Arizona (United States), Myanmar, China, Vietnam, Ethiopia, Tanzania, and Pakistan (Shigley et al., 1990, 2000; Kane, 2004).

Figure 1. These peridots from Sardinia (0.31–2.53 ct) are among the samples investigated for this report. Photo by Kevin Schumacher.

Some attractive peridot has also been found in Italy (Bianchi Potenza et al., 1989, 1991). Gem-quality stones (e.g., figure 1), typically <3 ct when faceted, have been recovered from an area near Pozzomaggiore, close to the city of Sassari, in northwestern Sardinia (figure 2). The olivine occurs in peridotite mantle xenoliths (figure 3) embedded in Plio-Pleistocene alkali basalts (Dupuy et al., 1987). These nodules range up to 30 cm in diameter and contain a typical peridotite assemblage of olivine, orthopyroxene, clinopyroxene, and spinel (Dupuy et al., 1987). The nodules are clearly visible in great abundance in this area, especially in excavations made for road construction and also in blocks used as building materials (Bianchi Potenza et al., 1991). The olivine-bearing basalts have been well known to Italian mineral collectors for years, though there are no reliable records of the amount of gem material recovered to date. The present study provides a detailed characterization of this Sardinian peridot.

Materials and Methods. We examined 10 faceted gems ranging from 0.14 to 2.53 ct (see, e.g., figure 1) and two pieces of rough measuring approximately 0.5–1 cm, all obtained from six fragments sampled in nodules recovered *in situ* from basaltic rocks near Pozzomaggiore. All the faceted samples were examined by standard gemological methods to determine their optical properties, specific gravity, UV fluorescence, and microscopic features.

Quantitative chemical analyses of major and minor elements (Mg, Si, Mn, Fe, and Ni) were performed on polished surfaces of two rough samples using an ARL electron microprobe in wavelength-dispersive mode. We determined trace elements (Li, B, Na, Ca, Sc, Ti, V, Cr, Co, Zn) in the same samples by laser ablation–inductively coupled plasma–mass spectrometry (LA-ICP-MS).

Mid-infrared (4000–400 cm^{-1}) spectra were collected from two rough samples in transmission mode using a Nicolet Nexus FTIR spectrometer. Powdered samples

---

See end of article for About the Authors and Acknowledgments.

GEMS & GEMOLOGY, Vol. 45, No. 2, pp. 130–133.

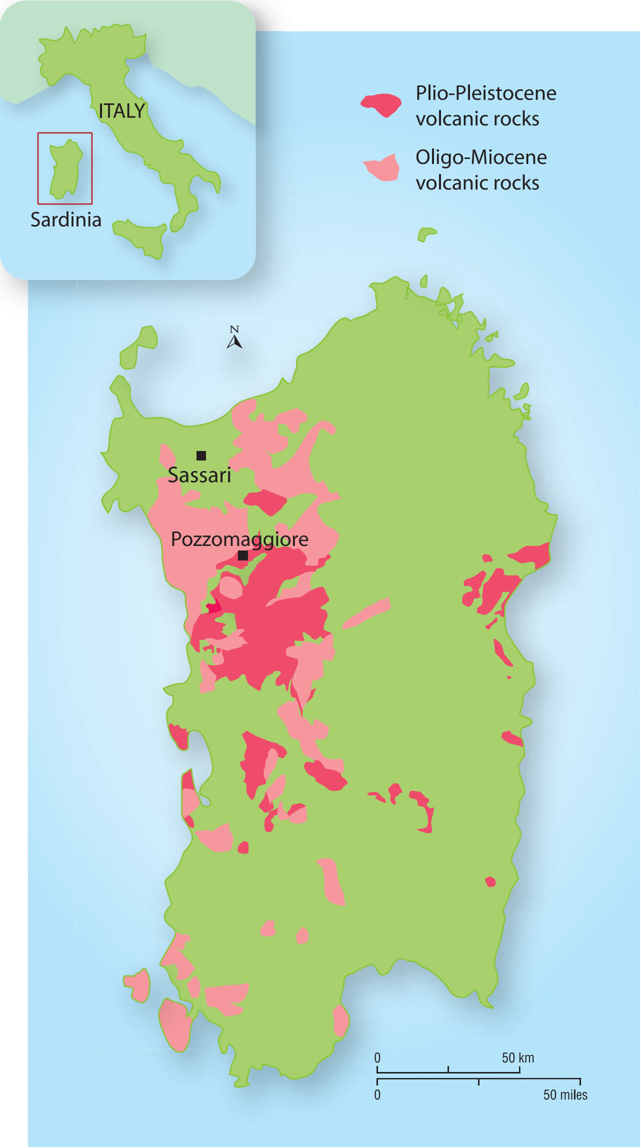


Figure 2. Gem-quality peridot is found in northwestern Sardinia, near the town of Pozzomaggiore.

Figure 3. Olivine-rich nodules containing pyroxene and spinel are hosted by basalts of Plio-Pleistocene age at the Sardinia locality. Photo by R. Bocchio.

were compressed into KBr pellets with a sample-to-KBr weight ratio of 1:100.

Unpolarized UV-Vis-NIR spectra were taken from two faceted samples (6.82 × 3.88 × 1.77 mm and 4.33 × 3.86 × 2.04 mm) with a PerkinElmer Lambda 950 spectrometer, equipped with an integrating sphere, over the 300–1300 nm range.

Results and Discussion. The gemological properties of the faceted samples (table 1) agree with those previously reported by Bianchi Potenza et al. (1991) for samples from the same area, and they are consistent with those of peridot from other geographic localities (Gübelin, 1981; Koivula, 1981; Koivula and Fryer, 1986; Führbach, 1998; Kane, 2004). For the most part, the samples appeared clean, with few internal features. The most common inclusions, present in almost all samples, were partially healed fractures (figure 4, left) and liquid inclusions. Four samples also contained some roughly round- to oval-shaped decrepitation halo cleavages, commonly known as "lily pad" inclusions (figure 4, right). More rarely observed were minute dark crystals (probably spinel, seen in three samples), parallel twinning (in two samples), and growth planes (in one sample).

Peridot is the gem variety of olivine that compositionally falls within the forsterite [abbreviated Fo; $\mathrm{Mg_2(SiO_4)}$] – fayalite [Fa; $\mathrm{Fe_2(SiO_4)}$] solid-solution series. Most gem peridots lie within the $\mathrm{Fo}_{80–95}\mathrm{Fa}_{20–5}$ range (Gübelin, 1981; Nassau, 1994; Krzemnicki and Groenenboom, 2008). Chemical analysis of the two rough samples (table 2) indicated a composition of $\mathrm{Fo}_{91}\mathrm{Fa}_{9}$ for both, which is consistent with that previously reported by Bianchi Potenza et al. (1991) and is typical of peridot from various localities (e.g., Stockton and Manson, 1983; Gunawardene, 1985; Führbach, 1998). The MnO content was low in both samples (average 0.13 wt.%), whereas the NiO average of 0.39 wt.% was close to the

TABLE 1. Gemological properties of peridot from Sardinia, Italy.

Color	Yellowish green
Pleochroism	Weak to moderate: α, β = green; γ = yellow-green
Optic character	Biaxial positive
Refractive indices	n_α = 1.650–1.652 n_β = 1.669–1.670 n_γ = 1.688–1.690
Birefringence	0.038–0.039
Specific gravity	3.32–3.36
UV fluorescence	Inert
Internal features	Partially healed fractures, liquid inclusions, "lily pad" inclusions, crystals, growth planes, traces of parallel twinning

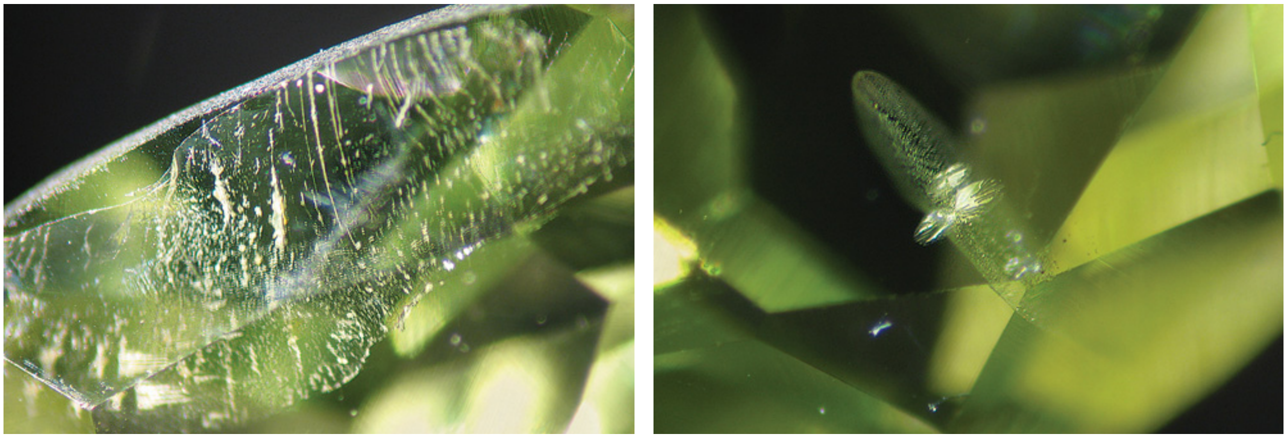


Figure 4. Sardinian peridot commonly contains partially healed fractures (left, magnified 30×). Decrepitation halo cleavages were present in some of the samples (right, magnified 45×). Photomicrographs by I. Adamo.

typical value of 0.40 wt.% reported in the literature for mantle olivine at ~$Fo_{90}Fa_{10}$ (Ishimaru and Arai, 2008). Our microprobe results are consistent with values estimated from the refractive indices, following Deer et al. (1982). Ca was the most abundant trace element found, followed in order of abundance by Co, Cr, Na, Zn, B, Ti, Sc, V, and Li, similar to the composition reported by Dupuy et al. (1987) for olivine from peridotite xenoliths of the Pozzomaggiore area.

The mid-IR spectra of both samples analyzed exhibited several absorption bands, located at about 982, 954, 885, 838, 605, 503, 469, and 415 cm^{-1} (figure 5). Their positions, known to be composition dependent (Duke and Stephens, 1964; Burns and Huggins, 1972), agreed with the Fe content of the samples.

The UV-Vis-NIR absorption spectra of our samples were characterized by a broad band at 1050 nm, with a shoulder at ~830 nm, in the near-IR range, and an increasing absorption toward the UV region (figure 6). Weak bands were also present at 403, 450, 473, 490, and 635 nm. The bands at 450,

TABLE 2. Chemical composition of two peridots from Sardinia, Italy.

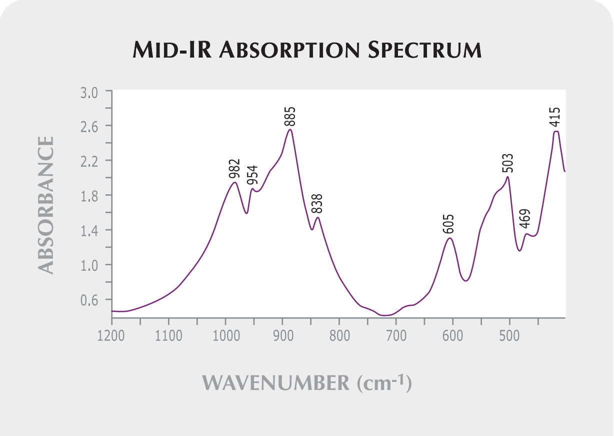
Chemical composition	Sample 1	Sample 2
Oxide (wt.%)[a]		
SiO_2	40.83	40.69
FeO	8.98	8.77
MgO	50.15	50.17
MnO	0.15	0.11
NiO	0.39	0.38
Total	100.50	100.12
Ions on the basis of 4 O atoms		
Si	0.994	0.993
Fe	0.183	0.179
Mg	1.819	1.825
Mn	0.003	0.002
Ni	0.008	0.007
Sum cations	3.007	3.006
Mol% end members[b]		
Fo	91	91
Fa	9	9
Trace elements (ppm)[c]		
Li	2.30	1.99
B	34.48	38.24
Na	95.67	73.21
Ca	548.50	453.94
Sc	4.87	6.35
Ti	10.51	8.81
V	4.18	4.15
Cr	157.51	181.35
Co	213.93	216.77
Zn	80.73	73.38

[a] *Obtained by electron microprobe analysis. Operating conditions: accelerating voltage = 15 kV, sample current = 15 nA, count time = 20 sec on peaks and 5 sec on background. Standards: forsterite (for Mg and Si), spessartine (for Mn and Fe), nickeline (for Ni), and kaersutite (for Na, K, and Ti). Na, K, and Ti were below the detection limit (0.01 wt.% oxide).*

[b] *Fo and Fa calculations omitted minor elements.*

[c] *Obtained by LA-ICP-MS; instrumental configuration and operating conditions are reported in Tiepolo et al. (2003). Rb, Sr, Y, Zr, Nb, Cs, Ba, and rare-earth elements were analyzed for but not detected.*

Figure 5. Sardinian peridot's mid-IR spectrum in the 1200–400 cm^{-1} range is characterized by absorption bands with composition-dependent frequencies.



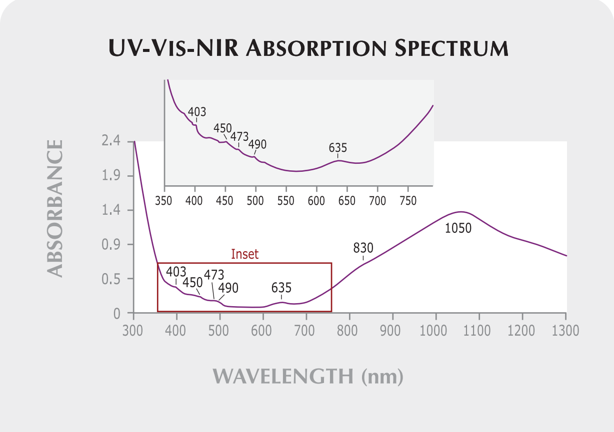


Figure 6. The UV-Vis-NIR spectrum of Sardinian peridot is mainly characterized by Fe^{2+} absorption features.

473, and 490 nm were visible with a hand spectroscope as well, with total absorption below ~440 nm. All these spectral features, which have been observed in peridot from other localities (see, e.g., Kammerling and Koivula, 1995; Führbach, 1998), are due to the presence of Fe^{2+} (Burns, 1970), confirming that iron is mainly responsible for the coloration. However, some absorption bands could also be contributed by the other chromophores in our samples, such as chromium (Rossman, 1988).

On the basis of the samples examined, the Sardinian peridot cannot be distinguished from peridot of other known localities.

Conclusions. The physical and chemical properties of peridot from near the town of Pozzomaggiore in northwestern Sardinia lie within the range of those reported for peridot specimens sampled worldwide. Thus far, because of the greater availability and larger sizes of peridot from other localities, the Sardinian material has remained within the Italian gemological community. The results of this study indicate that Sardinian peridot is worthy of attention as a gem material, and might have a market niche if properly mined and distributed.

ABOUT THE AUTHORS

Dr. Adamo (ilaria.adamo@unimi.it) is a postdoctoral fellow, and Drs. Bocchio and Pavese are professors of mineralogy, at the University of Milan, Italy. Dr. Prosperi is director of the Italian Gemological Institute laboratory in Milan.

ACKNOWLEDGMENTS

The authors are grateful to Dr. Massimo Tiepolo (CNR—Geosciences and Georesources Institute, Pavia, Italy) for LA-ICP-MS analyses, and Drs. Valentina Palanza and Giorgio Spinolo (University of Milan–Bicocca, Italy) for UV-Vis-NIR spectroscopy. The Geosciences and Geotechnologies Department of the University of Milan–Bicocca, and Dr. Vanda Rolandi, are acknowledged for assistance with taking photomicrographs. The manuscript benefited from the critical reviews of Drs. Lore Kiefert and Mary L. Johnson.

REFERENCES

Bianchi Potenza B., De Michele V., Liborio G., Nana G.P. (1989) Olivine from Val Malenco (Sondrio), Italy: A material of gemmological interest. *La Gemmologia*, Vol. 14, No. 3–4, pp. 23–33 [in Italian].

Bianchi Potenza B., De Michele V., Liborio G., Rizzo R. (1991) Olivines from Sardinia (Italy): A material of gemmological interest. *La Gemmologia*, Vol. 16, pp. 17–28 [in Italian].

Burns R.G. (1970) Crystal field spectra and evidence of cation ordering in olivine minerals. *American Mineralogist*, Vol. 55, No. 9/10, pp. 1608–1632.

Burns R.G., Huggins F.E. (1972) Cation determinative curves for Mg-Fe-Mn olivines from vibrational spectra. *American Mineralogist*, Vol. 57, No. 5/6, pp. 967–985.

Deer W.A., Howie R.A., Zussman J. (1982) Orthosilicates. *Rock-Forming Minerals*, Vol. 1A, 2nd ed. Longman, London, pp. 3–336.

Duke D.A., Stephens J.D. (1964) Infrared investigation of the olivine group minerals. *American Mineralogist*, Vol. 49, No. 9/10, pp. 1388–1406.

Dupuy C., Dostal J., Bodinier J.-L. (1987) Geochemistry of spinel peridotite inclusions in basalts from Sardinia. *Mineralogical Magazine*, Vol. 51, No. 362, pp. 561–568.

Führbach J.R. (1998) Peridot from the Black Rock Summit lava flow, Nye County, Nevada, USA. *Journal of Gemmology*, Vol. 26, No. 2, pp. 86–102.

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

Gunawardene M. (1985) Peridot from Ratnapura district, Sri Lanka. *Journal of Gemmology*, Vol. 19, No. 8, pp. 692–702.

Ishimaru S., Arai S. (2008) Nickel enrichment in mantle olivine beneath a volcanic front. *Contributions to Mineralogy and Petrology*, Vol. 156, No. 1, pp. 119–131.

Kane R.E. (2004) The creation of a magnificent suite of peridot jewelry: From the Himalayas to Fifth Avenue. *G&G*, Vol. 40, No. 4, pp. 288–302.

Kammerling R.C., Koivula J.I. (1995) An examination of peridot from Ethiopia. *Australian Gemmologist*, Vol. 19, No. 4, pp. 190–194.

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

Koivula J.I., Fryer C.W. (1986) The gemological characteristics of Chinese peridot. *G&G*, Vol. 22, No. 1, pp. 38–40.

Krzemnicki M.S., Groenenboom P. (2008) Gem News International: Colorless forsterite from Mogok, Myanmar. *G&G*, Vol. 44, No. 3, pp. 263–265.

Nassau K. (1994) Synthetic forsterite and synthetic peridot. *G&G*, Vol. 30, No. 2, pp. 102–108.

Rossman G.R. (1988) Optical spectroscopy. In F. C. Hawthorne, Ed., *Spectroscopic Methods in Mineralogy and Geology*, Reviews in Mineralogy, Vol. 18, Mineralogical Society of America, Washington, DC, pp. 207–254.

Shigley J.E., Dirlam D.M., Laurs B.M., Boehm E.W., Bosshart G., Larson W.F. (2000) Gem localities of the 1990s. *G&G*, Vol. 36, No. 4, pp. 292–335.

Shigley J.E., Dirlam D.M., Schmetzer K., Jobbins E.A. (1990) Gem localities of the 1980s. *G&G*, Vol. 26, No. 1, pp. 4–31.

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

Tiepolo M., Bottazzi P., Palenzona M., Vannucci R. (2003) A laser probe coupled with ICP-double focusing sector-field mass spectrometer for in situ analysis of geological samples and U-Pb dating of zircon. *Canadian Mineralogist*, Vol. 41, No. 2, pp. 259–272.