

OPAL FROM SHEWA PROVINCE, ETHIOPIA

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Opal occurs as nodules in volcanic rocks at a new gem opal locality in the Menz Gishe district of Shewa Province, Ethiopia. The opal field, still in the early stages of exploration, extends over several square kilometers. Opals from Shewa Province have near-colorless to white, yellow, orange, gray, or brown body colors; some show face-up play-of-color, and many have contra luz play-of-color. The gemological properties are consistent with those of other natural opals, and small particles are common inclusions. Preliminary stability tests indicate that much of the material absorbs water, and some crazes when exposed to light and heat.

Gem-quality opals, for the most part, come from two types of deposits: volcanic and sedimentary (FrondeL, 1962). Although the most significant deposits of gem opal—those in Australia—are sedimentary in nature (see, for instance, Wise, 1993), other important opal deposits are related to siliceous volcanic rocks. These volcanic occurrences include, among others, Querétaro, Mexico (see, e.g., Koivula et al., 1983; Gübelin, 1986; and Spencer et al., 1992), and Opal Butte, Oregon (Smith, 1988), with the lat-

ter's related deposits in Idaho (Broughton, 1972) and British Columbia (Downing, 1993).

Recently, opals were discovered at Yita Ridge in the Menz Gishe district of Shewa Province, Ethiopia. The opal-bearing rock is a nodular rhyolite (similar to that at Opal Butte). Material examined from the Ethiopian deposit included stones resembling "contra luz" (that is, play-of-color only visible with transmitted light) and "crystal" opal, as well as a fire agate-like opal that shows play-of-color on a dark brown body color (figure 1). As the deposit is still in the preliminary evaluation stage (T. Yohannes, pers. comm., 1996), its full production potential is unknown. However, early sampling results indicate that the opal-bearing rocks extend over several square kilometers.

ABOUT THE AUTHORS

Dr. Johnson is a research scientist, the late Mr. Kammerling was vice president for research and development, Mr. DeGhionno is senior staff gemologist, and Mr. Koivula is chief research gemologist at the GIA Gem Trade Laboratory, Santa Monica, California.

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BACKGROUND

To the best of our knowledge, the first report on gem opals from Ethiopia appeared in the February 1994 *ICA Gazette* (Barot, 1994). According to that report, Ethiopian opals were first seen in the Nairobi gem market in mid-1993. Some of these opals (obtained in Nairobi as being of Ethiopian origin, but with the precise locality unconfirmed) were subsequently examined and reported in the Spring 1994 Gem News section (Koivula et al.,

1994a). The Summer 1995 Gem News section contained a short entry specifically describing opals from the Yita Ridge area of Shewa Province (Kammerling et al., 1995).

LOCATION AND ACCESS

Yita Ridge, in the Menz Gische District of Shewa Province, is about 240 km (150 miles) northeast of Ethiopia's capital, Addis Ababa (Kammerling et al., 1995; figure 2). The opal field lies approximately 15–20 km north of Mezezo, about 8 km off the road between Mezezo and Hirute, which branches off the main road between Addis Ababa and Dese. The road between Yita Ridge and the Mezezo-Hirute road has been washed out for about 10 years, however, so the opal area is currently accessible only by mule trail or helicopter (T. Yohannes, pers. comm., December 1995).

The opal-bearing rocks outcrop along the north flank of Yita Ridge, at about 2,450 m elevation. The surrounding area is predominantly agricultural (figure 3).

GEOLOGY AND OCCURRENCE

The opal-bearing area lies in a large volcanic field just west of the northern Great Rift Valley of Ethiopia (the valley of the Awash River, in this area), according to Mr. Telahun Yohannes, of the Ethio-American Resource Development Corporation, a joint Ethiopia-U.S. firm that is mining the area. The opal nodules (figure 4) occur in a continuous layer of welded tuff (approaching obsidian in character), about 3 m thick, that lies between more weathered (decomposing) rhyolite layers. The beds have been uplifted and tilted slightly since deposition, but they are still more-or-less horizontal. The entire sequence of volcanic rocks, about 300–400 m thick, is probably part of the Amba Alaji rhyolites, which are Miocene in age (8 to 27 million years old; Merla et al., 1979). The opal nodules average about 10 cm (4 inches) in diameter.

PROSPECTING AND MINING

Only a small amount of material (about 200 kg) has been produced so far, all from surface and near-surface occurrences. Although the opal-bearing layer is primarily horizontal, the steep, gulch-like nature of the topography means that this layer outcrops in many places. The decision to begin commercial production is pending completion of surveys of the area to determine the economic feasibility of the deposit. It is expected that these surveys—tracking



Figure 1. Gem-quality opal was recently discovered in Shewa Province, Ethiopia. These four opals demonstrate the range in body color and play-of-color in stones from that locality. Clockwise from top, 7.52 ct cabochon, 2.15 ct round brilliant, 4.04 ct cabochon, and 2.31 ct triangle modified brilliant. Photo © GIA and Tino Hammid.

the opal-bearing outcrops, and assessing the quality and quantity of opal present—will be completed before the end of 1996. The few (less than 20) miners now working in the area use hand tools only, as the opal is too fragile for blasting (figure 5). In the future, however, road-grading equipment may be used to remove the decomposed rhyolite above the opal-bearing layer.

As of December 1995, on the basis of these outcrops of opal-containing rock, the gem field had been estimated visually to extend over an area of at least 7 × 7 km. It has also been estimated, from opal nodules randomly gathered from 12 area sites, that about 15% of the opal recovered is gem quality. About 1% of this gem opal shows distinct play-of-color.

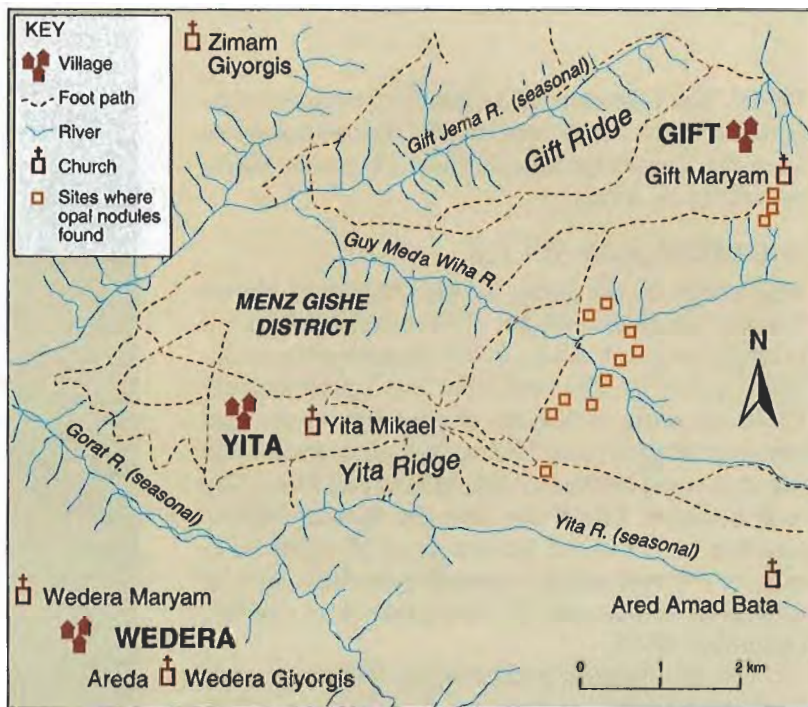


Figure 2. Opals are found along Yita Ridge in the Menz Gishe district of Shewa Province, Ethiopia. Location map on the lower left modified from Ethiopian Tourist Commission map (1992); opal locality map modified from one provided by Telahun Yohannes.

MATERIALS AND METHODS

We examined 19 fashioned stones—six faceted (0.55–4.80 ct) and 13 cabochons (0.83–19.71 ct)—and over 250 grams of rough, including sections of several different nodules. We viewed the face up colors using both fluorescent and incandescent illumination. We observed play-of-color with the stone against a dark background and spot illumination placed above and then perpendicular to the viewing direction (the latter to observe any *contra luz* effect). Refractive indices were measured with a Duplex II refractometer and a near-monochromatic, Na-equivalent light source. Specific gravity was determined by hydrostatic weighing; in those several cases where the stone absorbed water, we reported only the first result, which should be regarded as a minimum S.G. for that stone. Ultraviolet fluorescence was observed in a darkened room using a controlled viewing environment and a short-wave/long-wave UV lamp. Polarization behavior was noted using a GIA GEM Illuminator polariscope, and absorption spectra (for the body

color of the stones) were observed using a Beck prism-type spectroscope. The Chelsea color filter reaction was determined with illumination from a spectroscope base. Internal features were observed with a standard gemological microscope and bright-field, darkfield, and oblique fiber-optic illumination, as well as polarizing filters.

Trace-element chemistry was determined qualitatively by energy-dispersive X-ray fluorescence (EDXRF) spectrometry, using a Tracor X-ray Spectrace 5000 unit with a rhodium-target X-ray tube. Mid-infrared FTIR absorption spectra were taken with a Nicolet Magna-IR Model 550 spectrometer, with data collected in the range between 6000 and 4000 cm^{-1} . We employed X-ray powder diffraction analysis to identify some included materials, using a Debye-Scherrer camera mounted on a Siemens Kristalloflex X-ray generator.

Eight partially polished pieces were tested for durability. We exposed four samples to light and heat by placing them on a black surface, 8 cm from a 100-watt, high-intensity incandescent light, for

Figure 3. The area in which the opal nodules are found is very rural, consisting primarily of numerous small farms and villages. Photo courtesy of Telahun Yohannes.



24-hour periods up to a total of 192 hours (the temperature of the black surface reached 155°F—about 68°C) to simulate shop-window conditions. Another four pieces were immersed in water for a few hours and dried in air to a constant weight (about 24 hours), for two cycles, to test the effects of drastic humidity changes.

APPEARANCE AND GEMOLOGICAL PROPERTIES

Color. The fashioned stones were near-colorless, milky white, and yellow through orange to brown (again, see figure 1); one cabochon was pinkish brown. The two darkest stones had brown and black body colors; however, the darkest stone was a doublet that had been backed with black obsidian, which affected the apparent body color. Most of the material was suitable for jewelry (figure 6).

Play-of-Color. Two dark brown opals showed good play-of-color face-up, and the lighter stones had good (one example), moderate (four examples), weak (one example), or no play-of color when viewed face-up. Nine stones showed contra luz play-of-color. (The play-of-color is designated "contra luz" if it is seen with transmitted light—as described by Koivula and Kammerling [1988] and Smith [1988] for the Opal Butte material. For our nine contra luz samples, we saw play-of-color when we viewed the stones face up while they were illu-

minated from the side or rear; figure 7.) The black opal doublet had good play-of-color face up.

Diaphaneity. The fashioned samples were transparent to opaque. The darker they were, the less transparent they became.

Refractive Index. Refractive indices ranged between 1.40 and 1.45. In six cases, a second R.I. could be seen, usually at 1.45; this effect resembled the anomalous R.I. seen in some tourmaline (illustrated in Koivula et al., 1994b).

Figure 4. Opal nodules (the split one on the dark rock is about 10 cm in diameter) are abundant in the rhyolitic welded tuff, a rock that approaches obsidian in character. Photo courtesy of Telahun Yohannes.





Figure 5. Workers remove opal nodules from a sample pit in this outcrop of the opal-bearing welded tuff zone. Photo courtesy of Telahun Yohannes.

Polariscope Reaction. Twelve pale-colored stones showed weak-to-moderate anomalous double refraction (ADR) when viewed between crossed polarizing filters. Two darker stones showed no ADR.

Optical Absorption Spectrum. No spectrum was seen in the 14 lightest-color stones with the hand spectroscope. Three stones showed lower cutoff edges at 510 (yellow stone), 530 (yellowish orange), and 600 nm (brown). One mottled brown stone showed a band between 550 and 590 nm, a lower cutoff at 520 nm, and an upper cutoff at 670 nm.

Color filter. Two brown stones appeared red when viewed through the Chelsea color filter.

Fluorescence to UV Radiation. We observed the following reactions to long-wave UV radiation: faint-to-weak, even yellow-green (with weak phosphorescence); slightly chalky faint blue (moderate whitish blue); inert; faint uneven blue and yellow; and faint even orange. When the stones were exposed to short-wave UV, we saw: faint-to-strong,

even yellow-green (with no phosphorescence); slightly chalky faint (even) to weak (uneven) yellow-green; slightly chalky faint-to-weak blue; inert; faint even blue-white; faint uneven blue and yellow; and faint even orange. The doublet was inert to long-wave UV radiation, but it fluoresced a weak even yellowish green to short-wave UV.

Specific Gravity. The hydrostatic measurements ranged between 1.35 and 2.03; samples that did not soak up water were in the 1.87–2.03 range. Most of the near-colorless opals had specific gravities of 2.0 or higher. Seven stones changed their weights noticeably by soaking up water during the S.G. measurements: two near-colorless opals, two milky white opals, and one each orangy brown, light pinkish brown, and mottled yellow.

Microscopy/Inclusions. Solid inclusions were relatively common in the fashioned Ethiopian opals.

Figure 6. As these three pendants indicate, the Ethiopian opals (2.31–7.52 ct) make attractive jewelry stones. Jewelry courtesy of the Gold Rush, Northridge, California; photo by Shane F. McClure.





Figure 7. This piece of rough Ethiopian opal illustrates the *contra luz* effect: With darkfield illumination (left) no play-of-color is seen; with fiber-optic illumination from the side (right), strong play-of-color is visible. Photomicrograph by John I. Koivula; magnified 4 \times .

Most of the transparent-to-translucent gems contained tiny crystals of unknown composition. Perhaps the most distinct inclusions (because of their color) were randomly scattered red-brown grains (figure 8).

Intermixed with the red-brown grains were numerous small, opaque, black grains (figure 9). Some of these appeared a dark, brassy yellow when they were examined from above with a strong pinpoint fiber-optic light. Although most of the mineral grains were extremely small, a few of the largest were surrounded by small tension cracks (figure 10), which were probably caused by a difference in volumetric expansion between the inclusions and the enclosing opal.

Many of the red-brown and black inclusions appeared to have a square cross section or outline, indicating that they might be isometric. Even the largest of these inclusions was too small for X-ray diffraction analysis, however, so their identity is still unknown. Although there is no direct proof, we speculate that the black grains might be pyrite

(on the basis of their brassy metallic luster and square outline). Similarly, the red-brown grains might be pyrite altered to hematite.

Also present, although much less common, were tiny white to near-colorless grains that revealed no distinct form (visible in figures 8, 9, and 10; see also figure 11). Like the black and red-brown inclusions, these particles were too small to be identified by the methods available to us.

The most distinctive inclusion type—and the rarest—was observed in only one stone. These inclusions had the appearance of elongated, rough-sided “voids” or “tube systems” (figure 11). All reached the surface of their host and were partially packed with what apparently was a light brown-to-white, semi-translucent epigenetic matter. At the interface with the surrounding opal, the surfaces of these “tubes” were randomly spotted with tiny red-brown and black grains, similar to those previously described. In comparable inclusions seen in opals from Mexico (Koivula et al., 1983), the voids once contained hornblende crystals that had dissolved away and been replaced by, or partially filled with,

Figure 8. Tiny red-brown grains were visible with magnification in most of the Ethiopian opals. In some stones, small near-colorless crystals were also seen. Photomicrograph by John I. Koivula; magnified 50 \times .

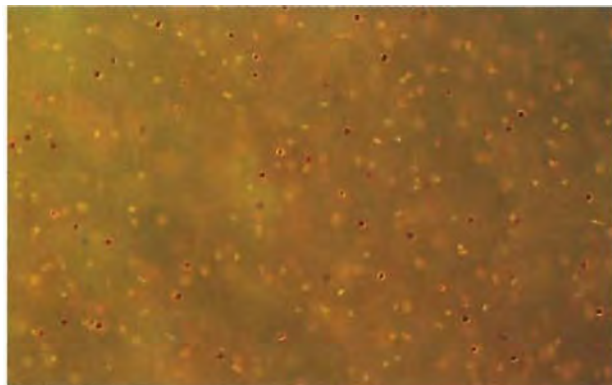
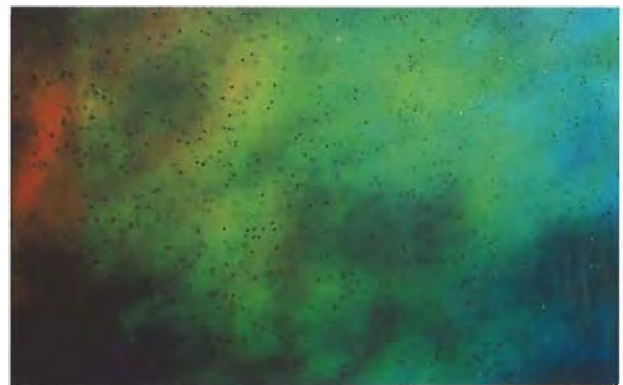


Figure 9. These small opaque grains (in a 4.77 ct Ethiopian opal) may be pyrite crystals. Photomicrograph by John I. Koivula; magnified 20 \times .



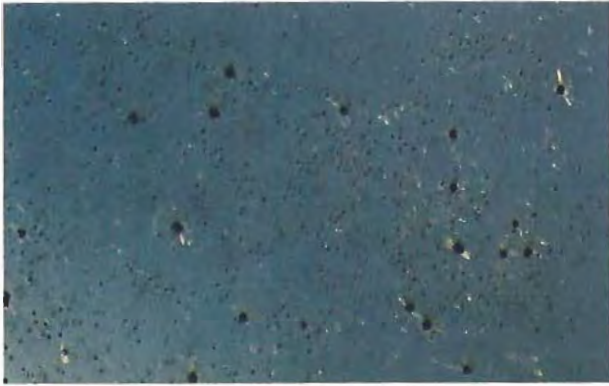


Figure 10. Some of the largest black mineral grains were surrounded by tension cracks. Photomicrograph by John I. Koivula; magnified 40 \times .



Figure 11. Rough-sided epigenetically filled "tubes," similar to those seen in some opals from Querétaro, Mexico, were observed in this 3.57 ct Ethiopian opal cabochon. Photomicrograph by John I. Koivula; magnified 15 \times .

limonite and a white kaolinitic clay. Because we could not perform destructive tests on the sample loaned to us for this study, however, we could not determine the identity of the filling material in this Ethiopian opal.

When opal nodules are freed from the rhyolite matrix, a black crust is sometimes visible on both the surfaces of the rough opals and on the rhyolite itself (figure 12); it may also be present in the cracks in some gem opals. An X-ray powder diffraction pattern, obtained from a scraping taken from one of these black crusts, matched that of the black manganese oxide ramsdellite.

Only the two opaque dark brown oval cabochons showed any obvious flow structure. This resulted from varying degrees of iron pigmentation, and it was manifested in the form of light brown veins and fingers extending into and through a much darker brown opal groundmass (figure 13). In one of these stones, a cell-like structure had formed where the light brown areas surrounded the darker areas. This was particularly obvious in oblique reflected light, in which the dark brown "cells" showed strong play-of-color (figure 14).

SPECTRAL AND CHEMICAL ANALYSES

Infrared Spectrum. All the stones showed a typical opal spectrum in the range between 6000 and 4000 cm^{-1} (see Fritsch and Stockton, 1987, for comparison).

Chemistry. Qualitative EDXRF analyses were performed on all 19 fashioned stones and on two pieces of matrix-free rough. For each stone, the only major element seen was silicon. Every stone also contained detectable trace amounts of calcium, iron, strontium, and zirconium; most stones contained trace amounts of potassium (20 stones),

rubidium (17 stones), or niobium (15 stones); and some stones also contained trace amounts of copper (10 stones), yttrium (8 stones), zinc (7 stones), lead (6 stones), titanium (5 stones), manganese (3 stones), chromium (2 stones), barium (2 stones), or gallium (1 stone).

STABILITY AND DURABILITY TESTING

Very little has been published about testing opals for durability. Pearson (1985) tested opals for crazing by refluxing them in flammable organic liquids; however, we did not try to duplicate this test because the materials involved are hazardous. A

Figure 12. Black flakes of ramsdellite were sometimes visible at the interface between the opal and its matrix and may occur in the cracks in some rough and fashioned Ethiopian opal. Photomicrograph by John I. Koivula; magnified 5 \times .



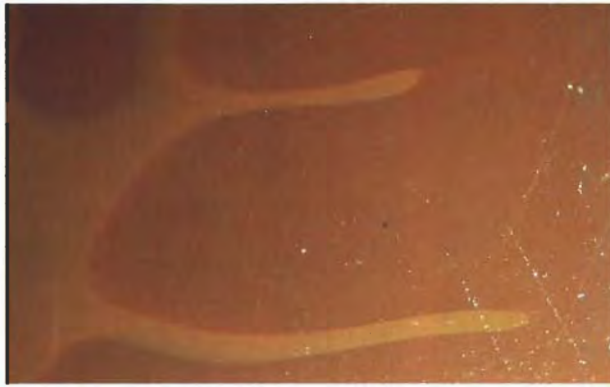


Figure 13. Flow structure is clearly visible in this 2.36 ct Ethiopian opal. Photomicrograph by John I. Koivula; magnified 25 \times .

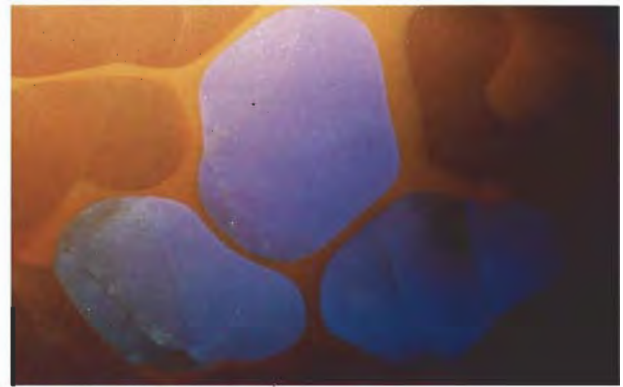


Figure 14. Play-of-color in this 4.04 ct dark brown Ethiopian opal is confined to distinct "cells," separated by lighter-colored brown opal, as seen here in oblique reflected light. Photomicrograph by John I. Koivula; magnified 15 \times .

practical "field test" for opal stability consists of exposing the material in a sunlit location for a few months, then recovering the undamaged remnants, according to Smith (1988), who also recommended a slow-drying technique to stabilize Oregon opal. He estimated that about 20% of the "fire opal" from Opal Butte, Oregon, was stable.

The lack of consensus in the literature led us to develop a few simple tests based on the assumption that gradual or sudden dehydration/rehydration was the process most likely to affect opals. Although we could not subject the fashioned stones we had borrowed to destructive testing, Mr. Yohannes kindly allowed us to do durability testing on some of the rough material. We had a flat surface polished on each of eight pieces of rough—two each of semi-transparent yellow *contra luz*, semi-transparent gray, semi-translucent yellow, and semi-translucent gray opal. We then divided the stones into two groups for testing, one for gradual dehydration and the other for sudden changes in water-vapor pressure. Because of the limited amount of material tested, we regard our results as informative but not definitive.

Gradual dehydration was simulated under "shop window" conditions: a bright light source and a black background (see "Materials and Methods").

Under these conditions, the *contra luz* and the semi-transparent gray opals did not change. The two other stones had developed cracks when first examined after 24 hours (figure 15); these cracks increased in size with subsequent exposure, but no new ones formed. It is interesting to note that during the first 24-hour test period, the semi-transparent gray stone developed a transparent outer layer (figure 16) that did not extend further into the stone on subsequent exposure, although cracks formed during the same period did grow. No additional changes were noted in any stone after 96 hours' exposure, which suggests that an exposure test such as this one may be sufficient to separate durable from easily crazed Ethiopian opals.

Sudden changes in water-vapor pressure were accomplished by repeated hydrostatic specific-gravity determinations. Between each test, we allowed the stones to dry completely (until the weight did not change). The *contra luz* and semi-transparent gray opals showed weight fluctuations of about 0.5–0.6 wt.% between wet and dry conditions, with significant cracking after the second humidity-change test. The two semi-translucent opals (yellow

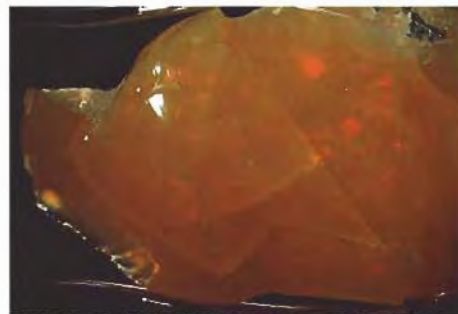
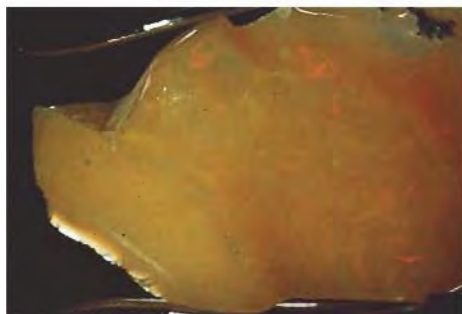


Figure 15. This 7.74 ct piece of rough yellow Ethiopian opal (left) cracked during 24 hours' exposure to light and heat (right). Photos by John I. Koivula.

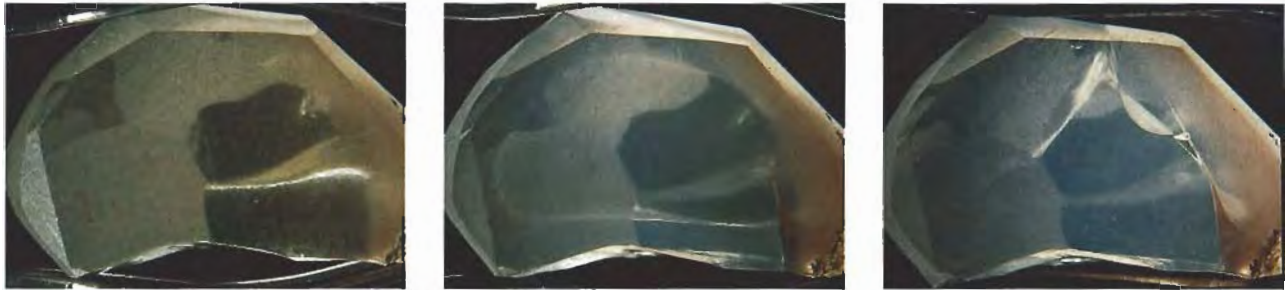


Figure 16. A 9.59 ct piece of semi-transparent gray Ethiopian opal (left, before testing) showed “clarification” of the less transparent areas and a few incipient cracks after 24 hours’ exposure to “shop window” conditions (center); by 48 hours (right), the cracks had extended through the stone. Photos by John I. Koivula.

and gray) developed less-pronounced cracking after two cycles, despite far greater weight fluctuations of about 11 and 18 wt.%, respectively. The weight gains (with soaking) and losses (as the stones dried) did not vary much with repeated soaking and drying, indicating no permanent gain or loss of water. Note, however, that we consider this test inherently destructive and do not recommend any “real world” equivalent—such as wearing an opal ring while washing dishes—for any opal.

In addition, the fashioned stones were exposed to variable temperature and humidity in open plastic bags for six months in our laboratory. During this time, external (relative) humidity fluctuated between about 10% and 70%. One stone—the black opal doublet—crazed, but none of the other stones was affected.

CONCLUSION

A new source for precious opal is being evaluated at Yita Ridge, in the Menz Gische district of Shewa Province, Ethiopia. The nodules occur in a broad range of body colors and play-of-color, including excellent contra luz material. Tiny red and black particles are pervasive throughout even the most transparent opals; among the other inclusions noted were hollow tubes and black platy manganese oxides. As with opals from other regions (including the similar volcanic environments of Querétaro, Mexico, and Opal Butte, Oregon), durability is a potential cause for concern. Only time will tell if full-scale mining at Yita Ridge will prove to be economically feasible. However, current indications are that some material will continue to reach the world market even if only small-scale mining continues.

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